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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4] 1937 [October

ERRATA.

Page 93, under Bajpai, M. P., *for* '(c)' *read* (*f*), *for* '*Op. cit.*,' *read* '*Proc. Twenty-second Ind. Sci. Congr.* (*As. Soc. Bengal*)', and *for* items '(*d*), (*e*), (*f*)' *read* '(*c*), (*d*), (*e*)'.

Page 94, under Chakravarti, *insert* '(*e*) Is Lametasaurus indicus an Armoured Dinosaur?' *Amer. Journ. Sci.*, Vol. XXX, 138-141, (August. 1935.)

Page 344, line 16 from bottom, *for* '7,800' *read* '9,000'.

Page 344, line 13 from bottom, *for* '26' *read* '28'.

he became a Superintendent on the 1st October 1891, officiated as Director from the 8th May 1896 to the 23rd November 1897, and retired from the service on the 2nd May 1904.

After his first season in the Godavari valley Oldham commenced that series of researches in the geology of the outer Himalaya which formed perhaps the main occupation, other than seismology, of a quarter of a century of varied fieldwork. In 1881-82 he accompanied the Manipur-Burma Boundary Commission to Manipur State and the Naga Hills, and in 1884-85 was with the Survey of India party in the Andaman Islands. In 1885-86 he toured the geologically unexplored desert region of north-western Rajputana, chiefly with a view to finding coal. In 1886-87 he worked in the Salt Range, in 1889-91 in Baluchistan and in 1901-02 in the Sulaiman Hills. From

1893 to 1899, interrupted by his appointment as Officiating Director and his investigation of the Assam earthquake of 1897, he was in charge of a party consisting of Messrs. P. N. Datta and E. W. Vredenburg in the Son Valley. His last field-work was in the Lower Chindwin and Pakokku districts, Upper Burma. After retirement he visited Burma again for a cold weather in a consultant capacity in oil to Messrs. Steel Bros. and Coy., Ltd.

This wide experience admirably equipped him for his selection, by the late Dr. W. King, to write the second edition of the official "Manual of the Geology of India" (1893), the groundwork of which he had earlier compiled in his "Bibliography of Indian Geology" (1888). The second edition of the Manual was in all important respects a new work, though based on the first edition by H. B. Medlicott and W. T. Blanford, and several of the new chapters were of universal geological interest beyond purely Indian problems. Before this he had edited his father's unpublished papers on the "Cachar Earthquake of 1869" (1882), on the "Thermal Springs of India" (1882) and the "Catalogue of Indian Earthquakes" (1883); these probably first attracted his attention to seismology, which culminated in his exhaustive memoir on the "Great Earthquake of 12th June 1897" (1900) and became the chief pursuit of the second half of his working life, subsequent to his retirement from the Survey.

Besides these major works, he was the author of over seventy papers, not only on the results of his stratigraphical seismological and economic work, but on many branches of physical geography, such as the cohesion of ice and its bearing on glacial erosion, ground-ice, land-slips, the smooth-water anchorages of the Travancore coast, Permian breccias, subterranean water supply, the ancient geography of India, flexible sandstone, facetted pebbles and blown-sand rock sculpture, the action of flowing water, theories of mountain formation, river valleys and rock basins, alleged Miocene man in Burma, the Allah Band of Kachh, sandhills and explosion craters. In Oldham's case versatility did not militate against that thoroughness which is characteristic of all his work. His originality of thought and breadth of vision carried his deductions from observations, far beyond mere description into the stage of elucidating new fundamental laws of science. He was thus the first to recognise (in 1900) the most important principle of seismography, that earthquake waves are split up into and propagated in three distinct forms, with different velocities and different paths, which are received at distant

places as the three well-known phases of the seismographic record. He also deduced (1906), from the records of distant earthquakes, that the earth has a core with physical properties very different from those of the surface shell which we know, and was able to calculate its diameter approximately as two-fifths of the total diameter of the earth. After his retirement from the Geological Survey in 1904 he lived for some time in the Isle of Wight near his friend and fellow seismologist, John Milne, then subsequently at Kew with his unmarried sister until her death, then in winter at Hyères in the south of France, where he made a physiographical and historical study of changes in the Rhone delta since Roman times; in summer he lived at Llandrindod Wells, for the benefit of his health, as he suffered from sprue.

Oldham was awarded the Lyell Medal of the Geological Society in 1908 and was President in 1920-22. He was elected a Fellow of the Royal Society in 1911 and served on the Council of the Society in 1920-21; he was also a Fellow of the Royal Geographical Society, a Member of the Institute of Mining and Metallurgy and an Honorary Fellow of the Imperial College of Science.

A. M. HERON.

NOTES ON THE GEOLOGY OF THE SECOND DEFILE OF THE IRRAWADDY RIVER. BY E. L. G. CLEGG, B.Sc. (MANCH.), *Superintending Geologist, Geological Survey of India.* (With Plate 28.)

Introduction.

The 'Second Defile' of the Irrawaddy is probably one of the, if not the, best known beauty spot of Burma. No informed traveller to Burma fails to include the river trip by steamer from Mandalay to Bhamo as part of his itinerary and the best scenic part of this trip is the eight to ten miles in which the river takes a big S-bend from immediately below the Bahmo basin in passing through the craggy heights of the second defile. Despite the popularity of this trip and the indelible impressions of the physical features which remain on all who carry it out, and notwithstanding the popularity of the view of the high crags of the centre of the defile as a guide book illustration, little is known of the geology of the rocks which form it.

It was visited by Griesbach and Nœtling sometime in the early "nineties", as the former[1] speculated on "certain more or less crystalline rocks chiefly limestones which occur in the midst of the metamorphic flexures, and seemingly conformable to the latter" as belonging to the Palæozoic groups and being possibly Silurian in age although actual proofs were wanting and the latter[2] published a map to accompany a "Note on the occurrence of Jadeite in Upper Burma" showing the rocks of the second defile as Silurian (?) Crystalline Limestone.

Since then the defile has been visited only by economic geologists *en route* for an outcrop of lignite which occurs at Lagatyan about four miles due south of Zinbon, a village occurring on the east side of the lower narrows of the defile. It was information derived from one of these—Mr. H. Day of Messrs. Bird and Company—that led to my visit. Mr. Day had informed me that he thought the defile limestones were Palæozoic and I had heard from Burma forest officers that rocks similar to the Mogok limestones occurred in the

[1] *Rec. Geol. Surv. Ind.*, XXV, p. 128, (1892)
[2] *Rec. Geol. Surv. Ind.*, XXVI, p. 26, (1893)

vicinity of Yanbo about fifty miles south of the defile. The physical features of the intervening country seemed to indicate that the hill ranges followed the strike of the rocks and there seemed a possibility of tracing the change in physical character of the rocks of the Mogok series into rocks of Palæozoic age along the strike. My object was to ascertain whether the rocks of the Mogok series were metamorphosed rocks of Palæozoic age or Archæan as had been thought.

Situation and physical features.

The defile proper lies between the villages of Sinkan (21° 9′ : 97° 0′) and Naungmo (24° 8′ : 96° 55′) the former on the left bank at the head of the defile and the latter on the right bank at the foot. One village, Zinbon, is situated in the defile about two miles from the lower end and is possessed of a well-kept forest rest house. The rest house stands on a small hill at the western end of the village; its position is ideal; it looks well from the river but it is even better than it looks. As it lies on the concave bank of one of the big bends of the river, excellent views of the river are obtainable from it both up and down stream, up-stream for about two miles, down-stream for about six miles. There are two bed-rooms and the verandah on which the traveller lives is large and is always cool, owing to the bungalow catching any wind that blows, as a valley opens out from the defile to the south-west.

The scenery is grand. Below Zinbon, that is, between Zinbon and Naungmo, high limestone cliffs form precipitous banks on either side and are very much undercut by solution weathering. Behind Zinbon a narrow flat-bottomed valley accommodates the last half mile of the Zinbon *chaung*; on the east of this valley are steep forest-covered slopes and knife-edged spurs; on the west is a plateau with a 200 feet precipice as its eastern boundary. The recent rocks forming this plateau have at one time continued across the river and a similar plateau occurs on the other side set back just a little from the river bank. Where the Zinbon *chaung* enters the river a small delta juts out into the main stream and forms a landing for the Irrawaddy ferry steamer if cargo justifies it; otherwise the odd passenger to Zinbon is landed by village dug-out or steamer dinghy. Further up the river and about two miles north-east of Zinbon, high limestone cliffs rise nearly a thousand feet sheer from the water, whilst nestling at the base is a most attractive little pagoda perched on a slipped block of limestone. Hence, lower banks

predominate up-stream until the last mile is reached, where once again high limestone rocks form precipitous banks on either side. These terminate abruptly to the east where the defile opens out into the Bhamo plain.

Geology. The rocks of the defile consist of the following series in descending order:—

(A) Sandstones, calcareous sandstones with intercalated conglomerates.	Late Tertiary sediments.
(B) Serpentines [seen intruded into (C) and (E)].	Intrusives.
(C) Calcareous sediments—limestones, indurated sandstones and shales.	Cretaceous series.
(D) Arenaceous sediments—fossiliferous rubbly sandy strata, the fossils remaining only as ferruginous internal casts.	
(E) Older indurated series very much folded and disturbed.	Older sedimentary series.

The oldest sediments form the high ridge consisting of steep forested slopes with knife-edged spurs which runs south from the defile immediately east of Zinbon. They are very much broken and consist of slates, quartzites and numerous volcanic rocks, including quartz-porphyries. Their age is doubtful as they are unfossiliferous but they continue southwards into the ridge of Tangte Hill which consists of rocks having all the physical characteristics of the Chaung-Magyi series, but as Tangte Hill as a whole forms an inlier in Tertiary sediments that is as much as can be said of them.

Oldest sediments.

On the foreshore east of Zinbon chocolate and fawn-coloured rubbly shales outcrop in the river and either underlying or intercalated in these about half a mile east of the village is a bluish grey, almost schistose, fine-grained rock consisting of very much crushed grains of quartz, orthoclase and plagioclase felspars, a little irregularly distributed biotite, and small cubic crystals of iron ore becoming limonitised. The groundmass is microcrystalline and the original character of the rock was probably of a fine-grained gritty nature.

The path from Zinbon to Sinkan turns south from the river 1½ miles east of Zinbon at an occurrence of serpentine which has a

brecciated rock on its western margin. To the south, rocks whose physical characteristics led me to class them as Chaung Magyis occur on the western flank of the serpentine. Where the 1,000 foot contour crosses the path, a chocolate-coloured shaly series similar to that seen on the foreshore occurs. It is difficult to know of what these chocolate-coloured shales consist. They are weathered, unfossiliferous, and appear much softer than the series. I have designated them Chaung Magyis; it is possible they are the remains of a much later series unconformably overlying them.

Cretaceous series.

The arenaceous sediments of the Cretaceous series are fossiliferous and occur from a third to half a mile west of Zinbon on the left bank of the river and are separated from the more calcareous sediments to the west by a hiatus in the sequence. They consist of dark, rather cleaved ferruginous mudstones, are very rubbly and have harder more sandy bands intercalated in them. The fossils occur as ferruginous casts but an *Orbitolina* which determines their age as Cretaceous has been isolated by Dr. Sahni from among them. On the point half a mile E. N. E. of Zinbon they are folded into a syncline. These sediments may be cut off from the harder and more massive Cretaceous rocks to the west by a fault, since Dr. Sahni has recently isolated an *Orbitolina* from the massive limestones; also the two formations may probably be in normal sequence, but similar Cretaceous sediments containing foraminiferal limestones apparently underlie massive limestones similar to those of the defile both near Mesan 10 miles to the S. S. W. and at Yanbo fifty miles to the S. S W.

Calcareous sediments.

The more calcareous part of the Cretaceous series is partly metamorphosed and consists of indurated limestones, sandstones, shales and their infinite combinations. These sediments as a whole dip N. N. E. and, with the exception of the reach which runs from Zinbon for $1\frac{1}{2}$ miles to the east, embrace the whole of the defile; the massive limestones of the series, which in places appear nearly 2,000 feet thick, form the precipitous banks, the more arenaceous sediments the jungle-covered slopes. The limestones have been extremely fossiliferous and the remains of what appear to be large molluscan shells protrude from the limestone rock in a most aggravating manner, as attempts to extract them are unavailing. Their occurrence is terminated at the lower end of the defile by

serpentinous intrusions. East of these serpentines the sediments are all very indurated, contorted and fractured and sometimes almost slaty. Bands of purer limestone occur in them, one on the right bank, about ten feet thick, dips N. N. W. at 70°. Approaching the main limestone band from the west on the right bank, contortions are seen to occur and the brecciation of the massive limestone seems to point to thrusting along the boundary. The contortions might on the other hand be due solely to incompetence in a more elastic series, as on the left bank half a mile south by east of Naungmo a band of almost pure limestone can be seen during the low-water season folded into a syncline.

Naungmo (24° 8′ : 96° 55′) to Zinbon (24° 7′ : 96° 56′). Calcareous sediments.

Only a general correspondence can be made out between the massive limestones on either bank of the river; on the right bank about 1,200 feet of limestone occurs in three main bands, the upper two being each about 300 feet thick and the lower 600 feet; on the left bank about 550 feet of limestone occurs in one band, apparently dipping N. N. W. by W. at 70°. Whether this lack of correspondence is due to normal faulting, or local faulting due to undermining by solution-weathering, it is not possible to say. It certainly does not seem possible for such thick bands to have petered out so much in the 600 yards which separates them. The limestone is all grey, fine-grained and argillaceous in character and is apparently all fossiliferous. So too are the intercalated calcareous shales. Underlying the massive limestone on the right bank are very mixed contorted strata. The limestone so far as can be seen dips north-west at 70°; contorted sediments are squeezed right under it at the junction and the boundary looks far from normal. For about 100 feet to the east of the boundary arenaceous rocks, which appear to be fairly regular, occur but pass eastwards into contorted mixed calcareous strata; they dip N. N. W. at 70°. Remote from the river these contorted rocks are overlain by horizontal late Tertiary sediments. On the left bank the massive limestone is underlain by mixed calcareous and arenaceous beds in which the more calcareous bands are up to thirty feet in thickness: they strike E. N. E. and are almost vertical. Further to the east no exposures can be seen for a short distance and then cleaved, rubbly, ferruginous, fossiliferous, sandy shales of Cretaceous age occur as a syncline on an E. N. E. strike.

Two miles north-east by east of Zinbon the same sediments are met with apparently on the continuation of the same line of strike. On the right bank, debris of the series from the heights to the north occurs along the river from half a mile E. N. E. of Zinbon, the only *in situ* exposures that are seen being the northerly continuation of the serpentines occurring $1\frac{1}{2}$ miles east of Zinbon. Limestone debris overlies these serpentines and continues along the bank to the main massive limestone exposure which forms the grandest feature of the defile. The cliffs are practically sheer for a thousand feet; they consist of bedded limestones, shaly in parts, and dip at low angles (20°--30°) at the south end, steepening to 45° at the north end; they are fossiliferous and bands of shelly limestone are clearly visible weathering out in the undercut cliffs near water-level. All attempts at obtaining identifiable specimens, however, proved unavailing. A huge fallen block provides a foundation for a small pagoda at the base of the cliff, but to realise the size and height of the block one needs to sail close along the bank in a dug-out; it cannot be appreciated from the deck of a passing steamer. On the left bank the only solid rocks seen north of the serpentine are limestones similar to those on the opposite bank and must be almost covered when the river is high; they dip N. N. E. at 25°, form no marked feature and most probably have been locally faulted from the sediments opposite by solution-weathering. Where the limestones cease at the upper end on the right bank they are underlain by ferruginous schistose shales which consist of very fine-grained quartz in a clayey ferruginous matrix. Contortions occur in the latter about 100 yards from the limestone and then the series takes on the strike seen below Zinbon; the dips are however less steep (about 40°). On the left bank opposite to the north end of the limestone outcrop, slaty shales dip S. S. E.; they are isolated from other exposures and their relations cannot be made out. North-east of the main limestone outcrop, the river follows the strike of the rocks to Pt. 386 on the one inch to the mile map where limestone concretions occur in the more arenaceous part of the sediments and limestone debris is found at the mouth of a small stream which there debouches into the main river. At the point just beyond and to the south a tough siliceous brecciated ferruginous rock occurs. Under the microscope this rock is seen to consist of a microcrystalline aggregate in which angular pieces of clayey ferruginous products

Limestones of the middle of the defile.

occur, the whole being split up by fine ramifying quartz veins.

Ferruginous siliceous breccia.

It appears to have the true characteristics of a fault-breccia in texture and strikes across the river with the sediments, occurring also on the other side. Intercalated in it on the right bank is a much fractured and broken micaceous grit consisting of angular grains of quartz and subordinate felspar in a microcrystalline indeterminate matrix in which a little biotite and muscovite are present. It is underlain by contorted calcareous rocks consisting of fine-grained quartz and a little felspar in a calcareous matrix dipping north-west at 40°. In these, lower in the sequence, purer limestone bands occur and occasionally a little contortion can be seen. On the left bank of the river, although a general correspondence with the opposite bank can be made out in the lower part of the series intervening between the breccia and the massive limestones of the eastern end of the gorge, in the upper part the rocks appear to be metamorphosed grits and conglomerates although limy bands do occur. One such $3\frac{1}{4}$ miles north-east of Zinbon is a grey patchy rather dolomitised looking rock. Under the microscope it was found to consist of grey fine-grained granular dolomite with larger patches which give a rather porphyritic look to the rock.

The rocks described appear to overlie the massive limestones of the eastern end of the defile but the relations at the actual boundaries are far from clear. One is not however likely to get clearer sections remote from the river. The massive limestones last mentioned form precipitous banks; at the eastern end they are very much brecciated and on the right bank terminate abruptly

Massive limestones of the upper end of the defile west of Sinkan (24° 9′ : 97° 0′).

where a 20-foot serpentine dyke running north and south occurs. On the left bank the limestones form the high peak (1985) south of the river. Shaly intercalations occur in the limestone series and on the left bank one very clear case of faulting can be seen. On the right bank, near the eastern end of the limestone occurrence, cleaved shaly calcareous strata occur as a dyke about three feet thick in the massive limestone; on the left bank the limestone has not the abrupt termination of that opposite, and metamorphosed shaly rocks apparently underlie it.

The limestones on both sides of the river dip north-west at high angles although in places, owing to the jointing, the dip appears to be much less. Stringers or thin bands of fossiliferous strata

and concretions occur and it is only from these that the true bedding can be arrived at. The disturbance of the overlying more sandy strata is well seen at the contact on the left bank.

Large scale mapping is really desirable in country such as this. The one-inch map fails to give a true idea of the inaccessibility of the country bounding the defile, whilst thick forest growth on all but the limestone scarps renders, remote from the river, the finding of one's position an almost impossible task. However, from the detail that I have been able to include, it appears obvious that the limestones of the lower and upper parts of the gorge are one and the same but are separated by faulting which bounds the main exposure in the centre of the gorge on its eastern flank. The eastern is the downthrow side of this fault but mapping of the outcrops in contiguous areas will be necessary before the direction of the fault can be specifically delineated.

On my first casual glance at the rocks of the gorge I thought the upper and lower limestones formed the northerly pitching ends of anticlinal structures; subsequent mapping showed however that this was not the correct interpretation.

Late Tertiary sediments.

Tertiary sandstones overlie the Cretaceous series at Zinbon and form the plateau-like high ground which lies to the west of the Zinbon-Lagatyan track and that which fills in the bay in the older series on the right bank of the river north-east of Zinbon. The forest rest house at Zinbon is built on slipped blocks of ferruginous conglomerate from the same rocks. The series is a very mixed one, as can be seen on the old overgrown track from Zinbon to Shwegu; it consists of fawn sandstones, flaggy calcareous sandstones, occasional white kaolinised sandstones and hard conglomerates with quartz pebbles up to four inches in diameter. Sometimes laterite caps the surface of the series. Along the stream which the path mentioned follows at the junction near Pt. 559 thick conglomerates containing pebbles of quartzite, slate and igneous rocks occur. Soft grits looking very like Irrawaddians of the type exposures overlie these conglomerates, whilst immediately north of Pt. 559, rubbly shales and soft sands and conglomerates dip south-south-west at 15°. A quarter of a mile east of Pt. 559 coarse conglomerates overlie a series of rubbly bluish shales and fine sandstones in which other thin (2 inch) conglomeratic bands occur. They dip S. S. E. at about 20°. Higher up the same stream near

Pt. 867 there is a cliff 100 feet high of practically horizontal conglomerates and intercalated sands and grits. Nowhere did I see any fossiliferous horizons in this series. The series is most certainly unconformable to the older rocks previously described; they have a much greater extent to the south and apparently previously had a much greater one still as a covering of the 'defile' rocks. They also occur as a series of conglomerates, sandstones and shales below the defile, and I noted in travelling down the river a gentle anticlinal fold in them along the right bank between Naungmo and Shwegu.

Above the defile they occur to the east of the serpentine dyke, which terminates limestones of the upper defile on the right bank, as a series of soft sands, whitish and fawn in colour, dipping north-west at 70°. Shales and hard sandstones are intercalated in them and the whole are overlain by recent alluvium.

Intrusive rocks.

Igneous intrusive rocks, now mostly altered to serpentine, terminate the Cretaceous series abruptly on both banks of the river at the lower end of the defile and the limestones on the right bank at the upper end: they also occur flanking the oldest sediments in the middle of the defile 1½ miles east of Zinbon and continue across the river to the north-west. Nowhere were they found intruded into Tertiary rocks either in the 'Second Defile' or to the south.

Specimens from the more unaltered parts of the intrusion at the lower end of the defile seem to point to an original doleritic rock; one, a dark bluish green medium-grained rock, consists of kaolinised plagioclase felspar, hornblende and interstitial quartz, the hornblende showing alteration to chlorite and iron ore; another, a medium-grained dark rock, consists of an interlocking aggregate of olive green hornblende and kaolinised plagioclase felspar; whilst still another consists of an ophitic mass of kaolinised plagioclase felspar, colourless amphibole and epidote, and is much speckled with iron pyrites.

On the spurs which run eastwards to the stream from the Zinbon-Sinkan track 1½ miles east of Zinbon and in the bed of the stream itself only altered igneous rocks are seen. A specimen from an exposure of light-coloured medium-grained chloritic rock consists of idiomorphic crystals of oligoclase, orthoclase and microcline, all rather kaolinised, in a matrix of chlorite; another, a fine-grained rock, consists of kaolinised indeterminable felspars, chlorite and colourless hornblende and might originally have been a dolerite.

In general, though, in this as in all the exposures, only dark green serpentine is encountered.

EXPLANATION OF PLATE.

PLATE 28.—Geological Sketch map of Second Defile of Irrawaddy river below Bhamo. (Scale 1 inch = $1\frac{1}{3}$ miles, approximate.)

DISCOVERY OF *Orbitolina*-BEARING ROCKS IN BURMA: WITH A DESCRIPTION OF *Orbitolina birmanica*, SP. NOV. BY

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CONTENTS.

INTRODUCTION.

During the course of his work on the geology of the Second Defile of the Irrawaddy river and the area around Mesan, ten miles to the S. S. W., and near Yanbo, fifty miles to the S. S. W., Mr. E. L. G. Clegg, Superintending Geologist, discovered certain fossiliferous horizons, the age of which, on the available field evidence alone, remained in doubt. Mr. Clegg, therefore, kindly sent the fossils to me for determination and the present paper is the result.

Resumé.

Briefly it may be stated that (1) the fossil determinations prove the occurrence of *Orbitolina*-bearing rocks in Burma. As far as we know, this is the first record of that genus in the Burmese region, the first record in fact of indisputable Cretaceous sediments in that area. The only other occurrence of supposed Cretaceous rocks in Burma is in the Arakan Yoma, but it has been disputed whether the rocks are of Cretaceous or of Triassic age[1]. Tipper records that *Cardita beaumonti*, d'Arch., a species characteristic of the Danian, occurs in these beds, but

[1] Tipper, G. H., *Rec. Geol. Surv. Ind.*, XXXV, p. 119, (1907), and Theobold, W. *Mem. Geol. Surv. Ind.*, X, Pt. 2, p. 134, (1873).

the Axials are clearly a mixed group (2) A new species in itself not being a satisfactory index to the age of the beds in which it occurs one must rely upon morphological comparisons with other forms for this purpose. Comparison of *Orbitolina birmanica* with orbitolines from the Tibetan region appear to indicate that a lower Cretaceous (probably the uppermost Barremian) age may be assigned to at least a part of the *Orbitolina*-bearing rocks of the Second Defile and the neighbouring area. (3) These comparisons further prove the extension of the Tibetan Lower Cretaceous sea into Burma, which is of importance from the palæogeographical view-point.

Stratigraphical sequence.

According to Mr. Clegg, the rocks of the defile consist of the following series in descending order[1] :—

(A) Sandstones, calcareous sandstones with intercalated conglomerates.

(B) Serpentines [intruding into (C) and (E)].

(C) Calcareous sediments,—limestones, indurated sandstones and shales.

(D) Arenaceous sediments,—fossiliferous rubbly sandy strata, the fossils remaining only as casts.

(E) Older sedimentary series,—older indurated series very much folded and disturbed.

The topmost beds (A), resting unconformably upon the older rocks, are entirely unfossiliferous and a Tertiary age is assigned to them by Mr. Clegg on lithological considerations and field evidence.

Arenaceous sediments.

The rubbly sandy strata (D), occurring at the following localities[2], have been examined :—No. 33, one mile south-west of Mesan (24° 1′ : 96° 52′), sheet 92 D/16; Nos. A, 42 and 43, half a mile north-west by west of Zinbon (24° 7′ : 96° 56′). Specimen No. 29 (only a fragment) from two miles S. S. E. of Mesan (24° 0′ : 96° 53′) Forest Rest House, is lithologically identical to the others, but contains no fossils. All these contain profuse remains of molluscan shells in the form of crushed fragmentary casts barely fit even for generic determination. Amongst these, fragments of shells may possibly be referred to the genera *Corbula, Trigonia, Nucula* and *Pecten*.

[1] *Rec. Geol. Surv. Ind.*, 71, Pt. 4, p. 352, (1937).

[2] The numbers refer to Mr. Clegg's field numbers painted on the specimens.

As previously reported[1], lithologically these beds are similar to those of the Assam Cretaceous placed in the upper division (Senonian) of that system by Spengler[2]. In fact the similarity is so great that had the writer not been able to isolate a single specimen of *Orbitolina*, which appears to be identical with *Orbitolina birmanica* described below from the associated limestones occurring in the Second Defile and elsewhere, a provisional correlation of these beds with the Senonian strata of Assam would have suggested itself. But the genus *Orbitolina* extends in range from the Lower Cretaceous to the base of the Upper Cretaceous only. It does not occur in rocks of younger age than the Cenomanian, that is, the lowermost division of the Upper Cretaceous. As will appear from what follows by comparison with other forms, the *Orbitolina* in the series (D) is assigned to the Lower Cretaceous.

Age of the Calcareous sediments.

In the other fossiliferous series (C), as aptly stated by Mr. Clegg, fragments of fossils protrude in a most 'aggravating' manner from the limestones. But in no case could anything definitely identifiable be recognised in the field. In the face of this it was perhaps natural, on the basis of field evidence alone, to assign these limestones to the Palæozoic, attaining as they do a thickness of 2,000 feet in places, which is rivalled only by that of the massive Palæozoic Plateau Limestones of Burma and the Shan States. Several thin sections examined by the writer equally failed to reveal fossil evidence that would throw light on the question of their age. The discovery of two or three specimens of *Orbitolina* in these massive limestones by the process of heating and sudden cooling whereby specimens became partially detached from the embedding matrix is, therefore, significant. In view of the paucity of material from these massive limestones, detailed comparison of internal structures are not possible, but externally the specimens isolated from samples collected at No. 6, Ku Taung (23° 24′ : 96° 5′), sheet 93 A/3, appear to be identical with the larger microspheric individuals of *Orbitolina birmanica* from No. 20 $\frac{3}{4}$ mile due north of Yanbo (23° 41′ . 96° 41′), sheet 93 A/10, and No. 21, Maingtha Chaung (23° 44′ : 96° 42′), sheet 93 A/10. One of the specimens from the massive limestones is figured in text-figures *e* and *f* and may be compared with figures *g* and *h* respectively, from near Yanbo. No

[1] *Rec. Geol. Surv. Ind.*, 71, Pt. 2, p. 169, (1936).
[2] *Pal. Ind.*, N. S. Vol. VIII, Mem. No. 1, pp. 1-73; Pls. I-IV, (1923).

megalospheric individuals, which in rock samples from Yanbo and Maingtha Chaung occur in about the same proportion as the microspheric, have been found in the samples from Ku Taung, though only a few blocks could be examined. On the available evidence therefore beds (C) and (D) should both be assigned to the lower Cretaceous, which means a great thickness of these sediments in this area.

With regard to the Calcareous sediments (C), this statement is made with some reserve as the writer feels that lack of sufficient material does not give complete confidence in expressing a conclusive opinion. However, the fact of their Cretaceous age cannot be doubted, especially as further evidence has become available since this paper went to press. Thin sections of specimen No. 59, from the right bank of the Irrawaddy river (24° 9′ : 96° 59′), 4½ miles E. N. E. of Zinbon, sheet 92 D/16, examined by the writer and definitely referred by Mr. Clegg to his Calcareous sediments, have conclusively proved the presence of *Orbitolina*, though the majority of specimens are crushed almost beyond recognition. Their specific identification is therefore not possible, but from their general characters (such as are available for examination in portions of isolated specimens that have partially escaped crushing) their identity with specimens from Ku Taung in the area to the southwest may be considered fairly certain.

The chief interest of specimen No. 59 from the Calcareous sediments is that it is the only specimen from the Second Defile which has yielded *Orbitolina* and has, therefore, enabled the writer to assign a Cretaceous age to the great thickness of the massive limestones of the Defile proper which are included by Mr. Clegg in his Calcareous sediments (C). The remaining specimens from the Calcareous sediments of the Defile noted in the following list and examined by the writer did not yield any orbitolines :—

Specimen No. 44	Irrawaddy river (24° 7′ : 96° 55′). One mile north-west by west of Zinbon (left bank). Sheet 92 D/16.	Grey, fine-grained, rather argillaceous limestone.
,, 52	Irrawaddy river (24° 8′ : 96° 57′). Two miles north-east of Zinbon (right bank). Sheet 92 D/16.	Crushed grey limestone, weathering to a dull black colour.

Specimen No. 53	Irrawaddy river (24° 8′ : 94° 57′). Two miles north-east of Ziubon (right bank). Sheet 92 D/16.	Dark grey, fine-grained limestone with calcite veins.

In addition the following specimen from the Calcareous sediments of the area ten miles to the S. S. W. of the Defile showed no trace of orbitolines :—

Specimen No. 35	One mile S. W. of Mesan Forest Rest House (24° 1′ : 96° 52′). Sheet 92 D/16.	Dark grey compact fossiliferous limestone.

The absence of orbitolines in the above noted specimens may, however, be due to paucity of material available for examination, to unsuitable conditions or to effects of crushing and recrystallisation, and does not necessarily imply that foraminifera did not exist in these rocks.

One could have wished that the fossil collections from these horizons were somewhat better and more extensive. But their paucity was inevitable, as the collections were made during the course of a traverse across a comparatively wide area. Considering the importance of the area it is very desirable that extensive collections should be made in order to elucidate more clearly the relationship and ages of the different formations.

We now come to the important question of the relative ages of the Calcareous sediments (C) and the Arenaceous sediments (D) of the Cretaceous series. According to field evidence the possibility of a fault between the two formations was suspected by Mr. Clegg. The presence as far as we know of the same orbitoline in the two formations appears to indicate that these are in normal sequence.

There is another point to which attention may be drawn. Mr. Clegg mentions certain volcanic intrusions into the Calcareous sediments (C) and the Older sedimentary series (E)[1] On the basis of the present determinations (C) is younger than series (D), and it is suggested that further examination will reveal the presence of similar intrusions in beds (D) also. In the areas mapped by the writer in the Northern Shan States, no intrusion into rocks of younger ages than the Chaung

[1] *Loc. cit.*, p. 352.

Magyis, which correspond to series (E) of Mr. Clegg are known. The massive thickness of the overlying pre-Cretaceous Mesozoic sediments and the Plateau limestones is entirely devoid of volcanic intrusions.

Incidentally it may be mentioned that Mr. D. N. Wadia[1] discovered a series of *Orbitolina*-bearing beds in Kashmir interbedded with a great thickness of volcanic rocks which may be compared with the *Orbitolina* beds of Burma now under consideration. Unfortunately, lack of time has not permitted the study of the relationship between the Kashmir and Burma orbitolines.

II.—DESCRIPTION.

Sub-family : *ORBITOLININAE.*

Orbitolina birmanica, sp. nov.

Holotype.—G. S. I. Type No. 16345.

[Plates 29 and 30 and text-fig. 1.]

Although a large number of specimens has been isolated, only a single species appears to be represented in the samples from near Yanbo, Maungtha Chaung and Ku Taung. Both microspheric and megalospheric forms are represented in profuse numbers at the first two localities but the proportion of microspheric individuals is slightly greater.

I.—External structure.

Microspheric form.—The microspheric individuals are depressed conical with a prominent central boss or mamilla from which the test slopes at first rapidly then gently to the fairly sharp margin (which shows a scarcely perceptible tendency to curve upwards) in the characteristic shape of a Chinese straw hat. The shell is irregularly circular in outline and slightly wavy (Plate 30, figs. 7-11, 17, and 19). The lower surface is concave, the degree of concavity varying to a certain extent. (Compare Plate 29, fig. 1, and Plate 30, figs. 1 and 2). The specimens are on the average about 5 mm. (or slightly less) in diameter but considerably larger individuals are known, the largest so far isolated being 13 mm., that is, nearly

[1] *Rec. Geol. Surv. Ind.*, LXVIII, pt. 4, p. 419, (1935).

half an inch across (Plate 30, figs. 9, 9*a*). Specimens of intermediate sizes have also been isolated. The largest specimen measures about 3 mm. in height, but the average height is not more than 2 mm.

Unfortunately, only a single specimen, out of the very large number isolated, shows the concentric lamellæ (Plate 29, fig. 7) and even in this the condition of the test is not such as to permit accurate measurements of the distance separating these.

Megalospheric form.—The megalospheric individuals are distinctly conical (Plate 30, figs. 12-16), the apex subtending, as in the corresponding form of *Orbitolina tibetica*,[1] Cotter, an angle of almost 90°. The maximum diameter of the base is about 4 mm., the height varies from 2 mm. to 3·5 mm. All the distinctly conical individuals are without the central boss or mamilla and the lower surface is either flattened or convex, the degree of convexity varying to a certain extent.

II.—Internal structure.

The internal structure of *Orbitolina* has been studied in some detail by Carter[2], Carpenter[3] and Fritsch[4] (who both referred certain species of *Orbitolina* to *Patellina*), by Martin[5] and more recently in concise detail by Douvillé[6]. Fortunately on account of the large amount of available material and by comparison with the already published studies, it has been possible to elucidate the internal structure of the Burmese species also in some detail. Plate 29, fig. 5, is a transverse section through a megalospheric (but somewhat depressed) form showing septa disposed in a regularly radiating manner along the periphery, but becoming irregular towards the central region. Plate 30, fig. 5, is a tangential section through another highly conical individual, parallel to and near the outer surface of the shell, that is the region where the septa are regularly disposed. The section is incomplete—the shell having been damaged in the course of preparation of the section. Plate 29, fig. 6, is another oblique section through a distinctly conical but relatively broader individual.

[1] *Rec. Geol. Surv. Ind.*, LXI, Pt. 4, p. 352, (1929).

[2] *Ann. Mag. Nat. Hist.*, Ser. 3, Vol. VIII, pp. 458-460, (1861).

[3] Introduction to the Study of Foraminifera, pp. 229-235, (1862).

[4] *Palæontographica*, Suppl. III, Lief. I, pp. 144-145, (1875).

[5] *Sammlungen des Geologisches Reichs-Museum in Leiden*, Vol. IV, pp. 209-229, Pls. XXIV and XXV, (1884-1889).

[6] *Bull. Soc. Geol. France*, 4^me^ Ser. Tome quatrienne, pp. 653-661, Pl. XVII, (1904).

The internal structure of the microspheric forms is identical to that of the high conical megalospheric forms except for the fact that in the former the transverse sections pass through several chambers and therefore become more complicated. Plate 29, fig. 2, is a transverse section through a microspheric form passing well above the basal surface. It passes through several chambers and shows a similar disposition of septa to that in the corresponding section of the megalospheric individual. The zigzag character of the septa, to which Douvillé and others have drawn prominent attention, is better seen in the darker part of the figure. The central portion represents the concavity of the lower surface filled with extraneous material. Plate 30, fig. 4, represents a transverse section, very close to the basal surface. The outer imperforate lamina and the supporting mesh structure are not seen in this section, but the quadrangular cells arranged in concentric circles, along the peripheral region, giving place towards the centre to triangular cells, similarly arranged, are clearly visible. The central dark area represents the basal concavity filled with extraneous material. Plate 29, fig. 1. and Plate 30, figs. 1 and 2, are vertical sections through microspheric individuals, the latter two passing through the central boss. Plate 30, fig. 6, is an enlargement of a portion of the specimens figured in Plate 29, fig. 2. All the sections show several minute foreign bodies dispersed through the shell structure. Martin[1], Cotter[2] and others have drawn attention to these in the case of the specimens from Borneo and Tibet studied by these authors respectively. The foreign bodies in *Orbitolina birmanica* consist both of quartz and calcite. These foreign bodies, '*fremdkorporschen*' of Martin, are clearly seen in Plate 30, fig. 6, which is magnified sixty-four times.

III.—AFFINITIES AND COMPARISON.

In structural characters the present species resembles *Orbitolina tibetica*, Cotter. The shape of the microspheric forms, however, is different in the two species. In *O. tibetica* 'the upper surface has a central boss which spreads into a saucer shaped disc'.[3] In *Orbitolina birmanica*, on the other hand, the shell slopes from the central

[1] *Loc. cit.*, p. 227, Pl. XXIV, figs. 10-12.
[2] *Loc. cit.*, p. 352.
[3] Cotter, G. de. P., *Loc. cit.*, p. 352.

boss to the margin which is scarcely upturned so that the boss is visible in lateral views, which is not always the case in *O. tibetica*.

The distinction is well illustrated in text-fig. 1. The megalospheric forms are very similar in both cases

The concentric lamellæ in *O. birmanica* are not seen except in one specimen only (Plate 29, fig. 7), so accurate comparison in this respect is not possible between the two species.

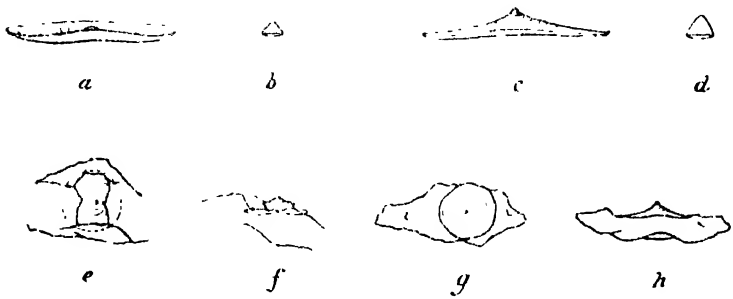

FIG. 1.—(*a*) *Orbitolina tibetica*, Cotter Microspheric form (Holotype) in lateral view showing the characteristic saucer-like shape (× 4). G. S. I. Type No. 14332.

(*b*) Same. Megalospheric form in lateral view. (Nat. size.) Paratype. G. S. I. Type No. 14327.

(*c*) *Orbitolina birmanica*, sp. nov. A comparatively large microspheric individual from near Yanbo, in lateral view. Margin scarcely upturned. (× 3). Compare with *O. tibetica*, (fig. 1*a*) above. Paratype. G. S. I Type No. 16349.

(*d*) Same Megalospheric form in lateral aspect (Nat size). Compare with *O. tibetica*, (fig. 1*b*) above. Paratype. G. S. I Type No. 16344.

(*e*) *Orbitolina cf. birmanica*, sp. nov. Reconstruction of imperfect specimen from Ku Taung (Calcareous sediments) in dorsal view. (Nat. size). G. S. I. Type No. 16357.

(*f*) Same specimen, lateral view. (Nat. size).

(*g*) & (*h*) Two views (Nat. size) of specimens figured in (*e*); for comparison with (*e*) and (*f*) respectively.

In external shape the microspheric form resembles *Orbitolina concava*, Lamarck, but according to Douvillé[1] the latter does not possess the thick conical form, both the microspheric and megalospheric individuals having the same shape. Distinction from *O. concava*, Lamarck, is, therefore, well marked. Incidentally it may be mentioned that Yabe and Hanzawa[2] consider that 'the specific

[1] *Comptes Rendus*, Vol. CLV, p. 571, (Sept. 1912).
[2] *Science Rep. Tohoku Imp. University, Sendai, Japan*, Second Ser. (Geology), Vol. IX, No. 1, p. 15, (1926).

name *scutum-trochus* given by D. K. Fritsch in an earlier date now seems more applicable' to the form described under *O.* '*concava*' from Borneo by Martin.

The species described from Shushal near Leh by Fossa Manchini[1] as *Orbitolina pileus* and *O. parma* are obviously megalospheric and microspheric forms of the same species. *Orbitolina parma* differs in shape from *O. birmanica*, but resembles *O. tibetica*, being like the latter saucer-shaped. This is clearly seen in Manchini's illustrations.[2] According to Cotter these two forms are distinct on account of the difference in the interspaces separating the concentric lamellea.[3] The vertical section of *O. pileus* given by Manchini shows a highly conical form, much more conical than any of the megalospheric individuals of *O. birmanica* so far isolated by the writer, but Manchini[4] states that intermediate shapes are also found, though these are not figured.

The forms bearing a much closer resemblance to *O. birmanica* are the lower Cretaceous forms from Tibet which Douvillé[5] has compared with *O. bulgarica* and *O. discoidea*. These, according to him, constitute forms A and B of *O. bulgarica* which is characteristic of the Uppermost Barremian.

IV.—CHEMICAL COMPOSITION OF THE TEST.

Some observations on the nature of the test may be made. Although Douvillé mentions that the test in the orbitolines is arenaceous[6], no analyses stating the percentage of silica content are given. Cotter[7] states that the silica percentage in *Orbitolina tibetica* is 5·26. Two analyses of the definitely conical (megalospheric) and the definitely discoidal individuals of *Orbitolina birmanica*, kindly made by Dr. R. K. Dutta

Chemical analyses.

[1] Spedizione Italiana De Filippi nell' Himalaia, Caracorum et Turkestan Chinese, Foraminifere del Calcaire grigio di Scivscivl (tago Pancong), (1913-14), Ser. II, Vol. VI, pp. 197-223, Pls. XXII and XXIII, (1928).

[2] *Ibid*, Pls. XXII, figs. 5 and 6. Pl. XXIII, fig. 4.

[3] *Loc. cit.*, p. 354.

[4] *Loc. cit.*, p. 198.

[5] In Seven Hedin, 'Southern Tibet,' pp. 145-146, Pls. IX, fig. 3; Pl. X, figs. 1-3, Pl. XI, fig. 1.

[6] *Bull. Soc. Geol. France*, 4th ser., Vol. IV, p. 655.

[7] *Loc. cit.*, p. 351.

Roy in the Geological Survey Laboratory, gave the following percentages :—

——	CaO.	SiO_2.	MgO.	Fe_2O_3 and Al_2O_3.
Megalospheric form	43·83	15·30	1·62	5·0
Microspheric form	43·17	14·88	1·47	4·08

The slightly higher percentage of Fe_2O_3 and Al_2O_3 in the microspheric forms may perhaps be accounted for by their lower concave surface in which slight traces of extraneous material would remain adhering to the shell. In other respects the correspondence in the percentages of CaO, SiO_2, etc., in the two forms is quite close, and the two analyses therefore confirm each other.

By comparison with the above table the wide divergence in regard to the chemical composition of the species from Burma and Tibet, which structurally appear to be allied, will be noticed. *O. birmanica* contains 15·30 per cent. silica, whereas according to analyses by Dr. W. A. K. Christie [1] the silica percentage in *O. tibetica* is 5·26, only one-third that in *O. birmanica.*

This confirms the conclusion arrived at by other workers regarding the relative importance of the chemical composition and structural characters of the test in Foraminifera, about which there is considerable divergence of opinion. I quote at length from Davies[2], who referring to Chapman's work on Foraminifera, wrote· ·

'later it was emphasised that forms within this '*Patellina*' group had arenaceous or sub-arenaceous tests, while others were purely calcareous ; so as Carpenter had already minimised the importance of structural distinctions .... the way was opened for what appears to be an undue emphasis laid upon the chemical composition of the test, to the ignoring of physical structure. Nor is this all for the impossibility of retaining all these types within a single genus has led to re-sub-divisions of the group being made, and we find old generic names are now apt to reappear in impossible connections. Thus Chapman first described certain new forms, which he found near Cairo, as '*Patellina ægyptensis*'[3] ; but afterwards, apparently because he found them to be sub-arenaceous, he referred them to '*Conulites ægyptensis*' [4]'.

[1] In Cotter, *Loc. cit.*, p. 351.
[2] *Rec. Geol. Surv. Ind.*, LIX, pp. 237-238, (1926).
[3] *Geol. Mag.* Decade IV, Vol. VII, p. 3, Pl. II, figs. 1-3, (1900).
[4] The Foraminfera, p. 157, (1902).

Davies has further pointed out[1] that this—

'is manifestly wrong and it is easier to believe that the composition of the test varied in closely allied forms than that morphologically very similar types should be placed far apart on the mere grounds of the chemical composition of the test'.

Similar views have been expressed by Schlumberger and Douvillé[2]. As the question is of importance and much general interest, I may be permitted to quote them in full—

' Les caractères tirés de la *constitution du test* sont d'importance tres différentes ; tandis que tous les naturalistes sont généralement d'accord pour considerer comme un caractére de premier ordre la nature perforée ou imperforée du test, *la composition meme de ce dernier, calcaire ou chitineuse et arénacée, ne parait avoir qu'une importance secondaire.* On constate en effet de grandes differences à ce point de vue dans des formes tres voisines et dont l'étroite parenté n'est pas contestable. Il faut ne voir là qu'un simple fait d'adaptation à des conditions d'existence particulières ; les formes nageuses ont normalement un test calcaire tandis que les formes qui vivent sur le fond sont les seules qui puissent emprunter à ce dernier des matériaux étrangères et les utiliser pour la construction de leur maison ; le but poursuivi est bien certainement ici une économie de matière ...... *C'est là un caractère de perfectionnement et qui n'est que secondaire au point de vue de la classification* de formes tres voisines comme les *Alveolina* et les *Loftusia* pouvant présenter les une un test porcelané, les autres un test arenacé et réticulé '.

The differences in the chemical composition of the tests in *O. tibetica* and *O. birmanica* are therefore not such as would preclude their essential affinity in structural characters.

V.—AGE OF THE *ORBITOLINA*-BEARING BEDS OF BURMA.

Orbitolina birmanica being a new species, the question of the age of the *Orbitolina*-bearing beds of Burma must rest either upon comparisons with other forms of known age or upon lithological similarities. The Cretaceous rocks nearest to the *Orbitolina* beds of Burma are those of the Arakan Yoma[3], Assam, Kashmir and Tibet. *Orbitolina* has not been recorded from the former two areas, but it has been recorded both from Kashmir and Tibet. Lithological comparisons between rocks of remote areas cannot be altogether reliable, as we have seen in the case of the Cretaceous rocks of Assam, though in the absence of fossil evidence or field

[1] *Loc. cit.*, footnote, p. 238.

[2] *Bull. Soc. Geol. France*, 4^{me} Ser. Tome V, pp. 291, (1905).

[3] As previously remarked, the presence of undoubted Cretaceous rocks in this area has not yet been proved, though their occurrence there is more than probable.

data, this remains the only available means of correlation. Comparisons with the other species of *Orbitolina* show that *O. birmanica* is closely allied to the forms referred by Douvillé to *O. bulgarica* from Tibet, which is a Lower Cretaceous (Uppermost Barremian) species. It is allied similarl to *Orbitolina tibetica* which, according to Cotter, is probably of the same age.

On the basis of these comparisons, I would place *Orbitolina birmanica* in the Lower Cretaceous and assign to it a probable uppermost Barremian horizon. This implies the extension of the Lower Cretaceous sea of Tibet into the Burmese region.

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VII.—EXPLANATION OF PLATES.

Orbitolina birmanica, sp. nov.

Holotype, G. S. I. Type No. 16345, the remaining specimens being paratypes.

PLATE 29. FIG. 1. Vertical section through a microspheric form ×16. G. S. I. Type No. 16333.

FIG. 2. Transverse section through a microspheric form passing above the base, showing the regular disposition of septa near the periphery, becoming irregular towards the central region. ×16. G. S. I. Type No. 16334.

FIG. 3. Vertical section through a megalospheric form with a convex base. ×16. G. S. I. Type No. 16335.

FIG. 4. Similar section through another slightly broader individual. ×16. G. S. I. Type No. 16336.

FIG. 5. Transverse section through a somewhat depressed megalospheric individual. ×16. G. S. I. Type No. 16337.

FIG. 6. Oblique section through a megalospheric individual. ×16. G. S. I. Type No. 16338.

FIG. 7. Upper surface, showing exposed concentric lamellæ. ×16. G. S. I. Type No. 16344.

PLATE 30, FIG. 1. Vertical section through a microspheric form. ×16. G. S. I. Type No. 16339.

FIG. 2. Similar section through a relatively more conical microspheric form passing through the central boss. ×16. G. S. I. Type No. 16340.

FIG. 3. Vertical section through a megalospheric form with damaged lower surface. ×16. G. S. I. Type No. 16341.

FIG. 4. Transverse section through a microspheric individual, passing very near the base. ×16. G. S. I. Type No. 16342.

FIG. 5. Oblique section through an incomplete megalospheric individual. ×16. G. S. I. Type No. 16343.

FIG. 6. Portion of specimen figured in Plate 29, fig. 2, enlarged showing foreign bodies. ×64. G. S. I. Type No. 16334.

FIGS. 7, 7*a*. Microspheric form. ×2. G. S. I. Type No. 16344.

FIGS. 8, 8*a*. Microspheric form. ×2. G. S. I. Type No. 16345.

FIGS. 9, 9*a*. An exceptionally large microspheric individual. ×2 G. S. I. Type No. 16346.

FIGS. 10, 10*a*. Microspheric form. G. S. I. Type No. 16347.

FIGS. 11, 11*a*. Young microspheric form. G. S. I. Type No. 16348.

FIGS. 12, 12*a*. Dorsal and lateral aspects of a megalospheric individual representing an almost perfect cone. G. S. I. Type No. 16349.

FIGS. 13, 13*a*. Dorsal and lateral views of a megalospheric individual ×2. G. S. I. Type No. 16350.

FIGS. 14, 14*a*. Dorsal and lateral aspects of a megalospheric form showing convex base. ×2. G. S. I. Type No. 16351.

FIGS. 15-16. Similar views of two megalospheric individuals ×2. G. S. I. Type Nos. 16352 and 16353 respectively.

FIGS. 17-19. Dorsal views of three microspheric individuals. ×2. G. S. I. Type Nos. 16354, 16355 and 16356 respectively.

NOTE ON ROCKS IN THE VICINITY OF KYAUKSE, BURMA. BY E. L. G. CLEGG, B.SC. (MANCH.), *Superintending Geologist, Geological Survey of India.*

In *Memoirs*, Volume XXXIX, Part 2, p. 34 La Touche in discussing the extent of the Archæan rocks states—

'Archæan rocks of Kyaukse.

'On the eastern bank (*i.e.*, of the Irrawaddy) the Palæozoic rocks of the Shan Plateau come right down to the plains of the Irrawaddy and the Archæan gneisses are found to occur only in a few outlying hills rising abruptly from the alluvium, including the Sagyin hills, mainly composed of crystalline limestone, which is largely quarried as a statuary marble, and Mandalay Hill which consists of the same marble traversed by veins of granite.

The gneisses appear again at the foot of the plateau scarp at Kyaukse, where there are large marble quarries, 25 miles south of Mandalay and beyond this they form a continuous band from 12 miles upward in width along the edge of the Southern Shan plateau, extending to the sea near Moulmein.'

Datta's division of the Kyaukse rocks.

Sheet 93 C/2, which includes Kyaukse, (21° 36′ : 96° 10′) was mapped by Mr. P. N. Datta during the field-season 1911-12. Mr. Datta divides the rocks of the eastern part of this area at the foot of the Shan Plateau north-east and east of Kyaukse town into the following series in descending order—

(1) Sandstones and quartzites—near Belin and between Belin and Kyaukse.
(2) Argillites and Quartzites one mile east of Kyaukse.
(3) Kinnaytaung limestone.
(4) Ubantaung shale.
(5) Datta-taung limestone.
(6) Sindetaung shale.

Of the relationships between (1) and (2) Datta says[1]—

Relationships of the Kyaukse rocks.

'As to the relationships of the sandstones and quartzites of the hills near Belin and between Belin and Kyaukse, as well of the argillites of the Kyaukse range: the argillites, *i.e.*, the shales with sandstone bands since transformed into argillites and quartzites overlie the Kinnaytaung limestone. The sandstones of Indaung, Kyaungywa and Belin would seem to form part of one and the same band and to overlie the Kyaukse argillites. The quartzites two miles E. by N. of Belin either form part of the Kyaukse argillites or of the sandstones of the Indaung hill; and if the latter the Kyaukse shale band had evidently thinned out considerably northwards.'

[1] Field Progress Report, Season 1911-12, p. 11.

Datta was unable to find any fossils in any of the rocks of the sedimentary series but placed them tentatively in the Palæozoic group.

Of the Kyaukse gneiss Datta says[1] :—

'The only outcrop of gneiss occurring in the area under examination is that of the Kyaukse hill (21° 36′ 30″ : 96° 10′ 30″). The question is :—was this crystalline mass originally granite, since altered through earth movements into its present schistose condition, or was it originally intruded as gneiss, converting the adjoining shales and limestones into argillites and marble, etc., pretty much as we see them now ?

Now at the south-eastern extremity of the mass, *i.e.*, by Tanda-u one mile south-east of Kyaukse, the sedimentaries do not exhibit signs of any great earth disturbance, the dips nearest the edge of the gneiss being about 15° (which however is found to increase steadily to 30° as one proceeds along the range eastwards). The Indaung sandstones again (about one mile north of the Kyaukse gneiss) show no indication of any plication or crumpling, but exhibit a steady dip to N. by E. at about 20°. Hence there being in this neighbourhood no indications of any such great disturbance of the earth's crust here as could have converted a granite into a gneiss, it seems that the foliation of the mass was original and not induced later on as a result of subsequent earth movements.'

On April 8th, in the course of a journey to Mandalay, I stopped for a day at Kyaukse and examined the rocks east of the town and also some railway ballast quarries which exist close to the road at Belin, five miles north of Kyaukse.

Of the former Datta states[2] :—

'Near Kyaukse (21° 36′ 30″ : 96° 10′ 30″)—from the very eastern edge of the town rises a precipitous hill which is seen to extend E.—W. as a range for about five miles. The high precipitous hill near the town constitutes the highest part of the range and is formed of a well-foliated felspar-quartz-biotite gneiss bearing the pagoda with the trigonometrical station (height 975 feet), conspicuous for many a mile around. The remainder of the range, *i.e.*, east of this gneissic mass, is composed of indurated micaceous sandy shale, grey thin banded quartzite, argillites, micaceous schist and crystalline limestone. The shale is almost unaltered in places, but in others it has been converted into an argillite and mica-schist. The crystalline limestone is well seen about four miles east of Kyaukse. The dip varies from 15° to 30°.'

Of the latter Datta states[3] :—

'The hill just S. E. of Belin (20° 40′ 30″ : 96° 10′ 30″) is formed of a coarse reddish sandstone rather thick-bedded with a dip of 20° to 30° north by east. On the

[1] Field Progress Report, Season 1911-12, p. 11.
[2] *Ibid.*, pp. 5-6.
[3] *Ibid.*, pp. 4-5.

northern part of the hill we find strings and veins of granite altering the associated rock into a quartzite.

North-east of the village is a high hill striking S. W.—N. E. Its south-western extremity, *i.e.*, the part nearest the village, bears the trigonometrical station 949 feet high and is formed mostly of quartzites, with strings of granite, while the rest of the range is due to granite.'

Kyaukse granite.

The Kyaukse granite or gneiss is undoubtedly intrusive into the series of sedimentary rocks which occur to the east as the strike of the gneissosity bands is north-south, whilst that of the sedimentary series is east-west, their dip being north at about 20°.

Indurated sedimentary rocks of Kyaukse area.

Further, with regard to the sedimentary series, Datta's description of them as argillites and quartzites is not quite correct. Practically all the rocks are calcareous. They consist, 200 yards east of the granite, of a series of well-bedded shaly limestones, very regular in character but with more sandy and shaly intercalations, the whole series weathering like calcareous gneisses. Some of the more solid limy bands have thicknesses up to four feet and the more shaly ones from 6″ to one foot, whilst individual bands of limestone vary from one inch upwards. Close to the granite the shales are phyllitic and at the contact include biotite-schists.

The main exposure of granite consists of quartz, felspar and biotite, large white felspars up to 6″ in length being streaked out along the gneissosity planes into an augen structure. On the flank of the exposure bands of granite contain tourmaline.

Quarrying at Belin was being carried out along the boundary of a granitic intrusion, granite underlying the alluvium to the west and tough metamorphosed calcareous sediments forming the hill to the east and apparently providing but a thin covering to the granite intrusion, as granite forms the main mass of the hill to the north-east. These sediments were of a much higher grade of metamorphism than those seen east of the Kyaukse granite and consisted of white marble, diopside-granulites, hornblende (actinolite)-gneiss and a dark greenish rock rich in epidote and diopside, whilst those east of Kyaukse consisted of calc-sericite-schists remote from the granite and a biotite-gneiss on the contact. The contact was not opened up as at Belin or possibly similar rocks to those at Belin would also have been found.

However that may be, there seems little doubt that Datta was quite correct in regarding the rocks of the area as a series of Palæozoic or later rocks intruded by granites and that La Touche erred in regarding the gneisses as of Archæan age.

Age and correlation of the Kyaukse rocks.

Datta's limestones pass northwards into the Plateau Limestones of La Touche and if the metamorphosed series of calcareous sediments are, as Datta says, younger than the limestones, then the granitic intrusions must be post-Plateau Limestone in age and therefore probably Mesozoic.

A continuation of the strike of the limestones as mapped by Datta in sheets 93 C/2 and 93 C/3 to the south takes them into Plateau Limestones of the Kalaw area in sheets 93 D/5 and 9. Further to the south Sondhi has mapped Coal Measures (Jurassic) overlying the Plateau Limestones in sheet 93 D/7 and granites intrusive into the same Coal Measures in sheet 93 D/12. The possibility exists therefore that the indurated calcareous sediments of the Kyaukse area, which are stated by Datta to overlie the massive limestones, were originally Coal Measures of the Shan States sequence. If this turns out to be correct then the age of the Kyaukse granite must be post-Jurassic.

A MESOZOIC CONIFEROUS WOOD (*Mesembrioxylon shanense, sp. nov.*), FROM THE SOUTHERN SHAN STATES OF BURMA. BY B. SAHNI, SC.D., F.R.S., *Professor of Botany, Lucknow University.* (With Plate 31.)

CONTENTS.

I.—INTRODUCTION.

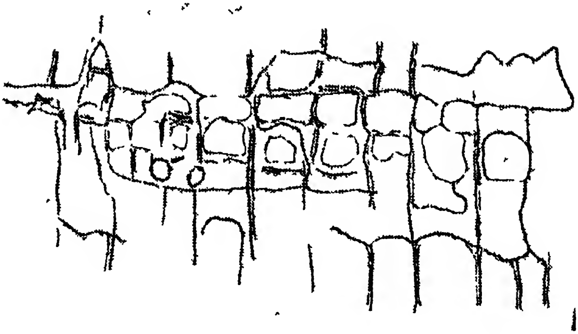
The following description is based upon a solitary specimen of silicified wood from the Loi-an series of Burma, kindly sent to me for investigation by the Director of the Geological Survey of India. Although by no means well preserved the specimen is described in some detail because, so far as I know, this is the only coniferous wood hitherto discovered in Burma. A number of vegetative shoots preserved as impressions have been described recently from the same series of strata.[1] The Loi-an series is regarded by the Survey as Jurassic, and the evidence of this fossil is not inconsistent with this view.

II.—DESCRIPTION.

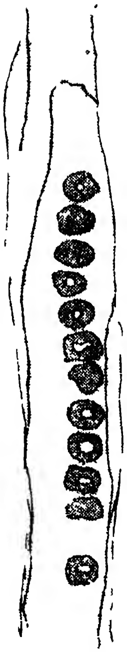
The specimen is about 5 cm. long and 6·5 cm. in diameter. The pith is very eccentrically placed, but this is probably due to the incomplete preservation of the secondary wood on one side. In a naked eye examination there is a faint suggestion of growth-rings, but these are scarcely visible under the microscope. The pith is well preserved, but the wood shows the pitting only sporadically.

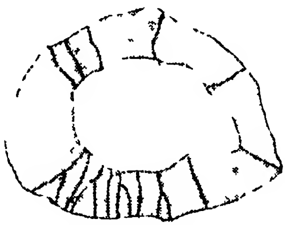
Transverse section.—The pith, 1·6 mm. wide, consists mostly of thin-walled isodiametric cells, among which a number of large

[1] Sahni, B., *Pal. Ind.*, N. S., Vol. XI, Pt. I, (1928), *Brachyphyllum* sp., p. 22, pl. II, fig. 26*a*; *Pagiophyllum burmense*, p. 25, pl. II, fig. 26*b*; pl. IV, figs. 48-51; *Cupressinocladus* (? *Thuites*) *walkeri*, p. 26, pl. IV, figs. 52-57, pl. V, fig. 60; *Cupressinocladus burmensis*, p. 28, pl. IV, figs. 58-59.



(1). $\times ca$ 310.





(3). $\times ca$ 310.

(2). $\times ca$ 310.

FIGS. 1—3.—*Mesembrioxylon shanense*, sp. nov.

stone-cells are scattered. About twenty-three primary xylem bundles project as rounded angles into the pith, giving the latter a stellate appearance (Plate 31, fig. 1). The narrowest tracheids are endarch, but their sculpturing is not preserved. The average diameter of the tracheids in the secondary wood is ·03 mm. The preservation is too poor to show in the transverse section of the wood either the pittings of the tracheids or the structure of the medullary rays.

Tangential section. The tangential section (Plate 31, fig. 2) shows that the medullary rays are all uniseriate and as a rule one to two cells high. The highest ray observed is four cells. The cells appear laterally compressed and elliptic in section. No tangential pits have been seen, but the preservation is too bad to make it certain that they were absent.

Radial section. Plate 31, fig. 3 shows a radial section passing through two protoxylem bundles, with the pith between. Portions of the primary metaxylem and the secondary wood are also seen. The thin-walled cells of the pith, as a rule isodiametric, are sometimes considerably longer than broad; they usually have transverse end-walls. The stone-cells are of simple shape and usually about two or three times as large as the ordinary cells of the pith; their walls are moderately thick, leaving a lumen about half the diameter of the cell (Plate 31, figs. 3, 6; text-fig. 3). The sculpturing of the protoxylem is not preserved. The radial pits of the secondary tracheids, rarely preserved, are uniseriate, circular and separate (Plate 31, fig. 4; text-fig. 1). The pore may be either circular, or elliptic and oblique. The pits in the field, visible only in a few medullary rays, are large borderless pits of the type of eiporen, one or at most two in each field (Plate 31, fig. 5; text-fig. 2). Most of the tracheids show a deceptive appearance of thick dark coloured transverse septa; this is due to the presence of quantities of resin which occurs in the form of plates or spools with a convex or concave meniscus (Plate 31, figs. 2, 3). Although it is possible that here and there parenchymatous cells with transverse end-walls may be present, I have not found any undoubted cells of this nature.

Systematic position. The structure of the wood corresponds most nearly to the diagnosis of the genus *Mesembrioxylon* Seward.[1] This admittedly artificial genus was founded to include woods previously

[1] Seward, A. C., Fossil plants, Vol. IV, *Cambridge*, p. 203, (1919).

described under *Podocarpoxylon* Gothan, *Phyllocladoxylon* Gothan and *Paraphyllocladoxylon* Holden. Our species shows a combination of characters which is not found in any other wood known to me. Its chief distinctive features are the faintly visible growth-rings combined with the very low medullary rays, the eiporen, the very numerous resin plates in the tracheids and the large stone cells in the pith.

Mesembrioxylon shanense, sp. nov.

Diagnosis. Growth-rings scarcely visible under the microscope; resin canals absent, but numerous resin plates or spools in the tracheids; wood parenchyma not seen. Pith parenchymatous with scattered stone cells, surrounded by numerous endarch primary bundles. Radial pits uniseriate, circular, separate, pore round or elliptic and oblique. Medullary rays uniseriate, very low, usually 1-2 cells high, cells laterally compressed, pits in the field one (rarely two) large, borderless (Eiporen).

Locality.—In the railway cutting half a mile east of Loi-an station, near Kalaw, Southern Shan States. Collected by Dr. L. A. N. Iyer, Geological Survey of India.

Horizon.—Loi-an Series.

G. S. I. Type No.—16358.

Comparisons.—In individual features our wood resembles several species, *e.g.*, *M. schwendæ* (Kub.) Sew.[1] from the Cretaceous or Tertiary of Austria; *M. gothani* (Stopes) Sew.[2] from the Aptian of England; *M. parthasarathyi* Sahni[3] from the Upper Gondwanas (Jurassic) of Southern India; *M. malerianum* Sahni[4] from beds in Rewah, Central India, which most probably also belong to the Upper Gondwanas[5] and *M. sewardi*, Sahni[6] from the Walloon series (Jurassic) of Queensland. In the first three and in the last named species the pith has been found preserved, and in all cases it contains sclerotic cells, but there are several points of difference. Thus in the Madras species the medullary rays are much higher and the

[1] Seward, A. C., Fossil Plants, Vol. IV, p. 209, (1919); Kubart, B. *Oest. Bot. Zeitschr.*, LXI (5), p. 161, (1911).
[2] Seward, A. C., *Loc. cit.*, p. 207, (1919); Stopes, M. C. *Brit. Mus. Catalogue*, p. 228, (1915).
[3] Sahni, B., *Pal. Ind.*, N. S., Vol. XI, Pt. II, p. 60, (1931).
[4] *Ibid.*, p. 63.
[5] *Ibid.*, p. 115.
[6] Sahni, B., *Queensland Geol. Surv.* Publication No. 267, p. 23, (1920).

field pits are not eiporen. *M. gothani* seems a little closer to our species, but the rays are somewhat higher, while the pits in the field are not so large and are oval in shape; moreover, the ordinary cells of the pith, apart from the stone cells, are rather thickwalled. In *M. schwendæ* the medullary rays are higher, and the field pits are usually bordered, with an obliquely vertical pore, though sometimes there is a single large eipore. *M. malerianum* resembles our plant in its very low medullary rays, but has several bordered pits in each field. Lastly, *M. sewardi* has in each field a single large circular eipore, resin spools in the tracheids and low medullary rays—features in which it approaches *M. shanense*. But the two species are very different in the structure of the pith, which in the Australian form consists entirely of thickwalled cells.

M. sewardi, moreover, has very sharply defined growth rings, even the spring and autumn wood within each ring being clearly marked off from one another.

III.—AFFINITIES.

In the first place we might enquire if this wood can have belonged to any of the conifers whose vegetative shoots have been described from the Loi-an series. A correlation of fossil woods with detached vegetative shoots must always remain a matter of uncertainty, because inevitably our genera have to be more or less artificial. The wood genus *Mesembrioxylon*, as Professor Sir A. C. Seward has clearly stated,[1]

> 'undoubtedly includes species which if additional data were available would be assigned to distinct genera'.

Although, thanks chiefly to the work of Professor Gothan, our knowledge of coniferous woods is now sufficiently advanced to make it highly probable that *Mesembrioxylon* is pre-eminently a genus of Podocarpinean conifers, we must not forget that this genus sometimes grades into *Cupressinoxylon* in such a way as to make the distinction almost vanish. In dealing with these borderline species the only helpful criterion lies in the medullary ray pits of the spring wood,

> 'the pore being narrow and more or less vertical in *Mesembrioxylon* ("podocarpoid pitting" of Gothan), wider and more nearly horizontal in *Cupressinoxylon* ("cupressoid pitting" of Gothan)'.[2]

[1] Seward, A. C., Fossil Plants, Vol. IV, p. 206, (1919).
[2] Sahni, B., *Pal. Ind.*, N. S., Vol. XI, Pt. II, p. 53, (1931).

This criterion can only be usefully employed in well preserved specimens in which the spring wood is available. Our specimen is neither well preserved nor has well marked growth-rings. But fortunately the critical character of the medullary ray pits is quite well seen: wherever the pits in the field are preserved at all they are clearly of the type of eiporen, that is, large, borderless pits, in which the question of the vertical or horizontal position of a slit does not arise. That section of *Mesembrioxylon* in which the field pits are of this type seems to belong to the Podocarpineæ rather than to the Cupressineæ. Sclerotic cells in the pith are also a well marked character of the Podocarpineæ. *Our specimen is therefore most probably the wood of a podocarp.*

As regards the vegetative shoots, two of the four species were referred to *Cupressinocladus* (*? Thuites*), one to *Pagiophyllum* and one to *Brachyphyllum*. The probable affinities of these shoots have already been discussed elsewhere.[1] Only the first-named genus can be assigned with any confidence to a known family, namely the Cupressineæ, and it seems out of the question that our wood should belong to that group. One or two species of the genus *Brachyphyllum* possibly belong to araucarian conifers but the affinities of the majority of species are quite unknown; some of them may well be Podocarpineæ. *Pagiophyllum* is an equally artificial group, among which members of more than one family are almost certainly represented; and it is not impossible, though of course we have no proof, that *Mesembrioxylon shanense* belonged to *Pagiophyllum burmense*. Without further data, however, these discussions are rather futile.

The upshot is that our fossil, the only petrified conifer yet known from Burma, is very probably the wood of a podocarp which may or may not have belonged to one of the species of vegetative shoots described from the same region. As we shall see presently, the question of the affinities of the plant is important from the geographical point of view.

IV. PALAEOGEOGRAPHICAL CONSIDERATIONS.

It would be interesting to know whether the affinities of our fossil lie more with some species from the Far East, or with members of the Gondwana flora. Palæobotanical evidence clearly suggests

[1] Sahni, B., *Pal. Ind.*, N. S., Vol. XI, Pt. 11, p. 105, (1931).

that during the early Mesozoic era Szechuan, Yunnan, and Tonkin formed parts of a botanical province rather distinct from Gondwana Land.[1] About the distinctness of these two provinces in the late Palæozoic there is no doubt whatever: this is shown by the great contrast between the *Glossopteris* flora of India and Australia and the *Gigantopteris* flora of China and regions further south. It was this palæobotanical contrast which first suggested that the two regions must have been originally separated by an ocean barrier;[2] and the belt of marine sediments in the meridional range of mountains in the Assam-Burma-Malaya region must obviously have formed the barrier in question. Towards the end of the Palæozoic and the early Mesozoic the barrier appears to have become less effective: the sharp contrasts of the earlier floras were not maintained. It is a significant fact that the mountain belt in Burma lies *west* of the Shan plateau, which therefore cannot have formed a part of Gondwana Land. Detailed work on the fossil floras of the Shan States should probably confirm this suspicion, already suggested in 1931[3] by the affinities of some of the conifer shoots from the Loi-an series. In fact all the available geological evidence, recently summarized by Wadia,[4] seems clearly to go in support of this view.

The above considerations suggest that this fossil wood from East Burma should be compared with any species of Mesozoic conifers that may be found in China and Japan or in other parts east of the meridional mountain belt of Burma-Malaya. I am not aware of any fossil woods of the *Mesembrioxylon* type yet described from the Far East, but our knowledge of petrifactions from that region is still very imperfect.

V.—GEOLOGICAL AGE.

As stated, the genus *Mesembrioxylon* was founded to include woods previously described under *Podocarpoxylon* Gothan, *Phyllocladoxylon* Gothan and *Paraphyllocladoxylon* Holden. These genera, taken together, range in geological age from the Jurassic to the Tertiary.[5] The new species therefore does not contradict a Jurassic age for the beds in which it was found.

[1] Sahni, B., *Journ. Ind. Bot. Soc.*, October 1936.
[2] Halle, T. G., *Palæont. Sinica*, Ser. A, 2(i), pp. 288-290, (1927).
[3] Sahni, B., *Pal. Ind.*, N. S., Vol. XI, Pt. II, pp. 116-117, (1931).
[4] Wadia, D. N., *Himalayan Journal*, Vol. VIII, pp. 63-68, (1936).
[5] Seward, A. C., Fossil Plants, Vol. IV, p. 173, (1919).

VI.—SUMMARY AND CONCLUSIONS.

This new species of *Mesembrioxylon* from the Loi-an series, probably the wood of one of the Podocarpineæ, is characterised by poorly marked growth-rings, very low medullary rays, large eiporen in the field, numerous resin plates in the tracheids and a thin-walled pith containing large scattered stone cells.

The only fossil conifers previously known from this area were a few vegetative shoots collected in the same series of strata.

The Podocarpineæ may be represented among these shoots but we cannot say this for certain, as some of the shoots belong to highly artificial genera (*Brachyphyllum*, *Pagiophyllum*). Whether the fossil wood belonged to the same species or genus of conifers as one of these shoots must therefore also remain an open question.

Although poorly preserved, the fossil is of interest as the first petrified conifer to be found in Burma, a region of considerable importance from the plant-geographical point of view. Previous work on the flora of the Loi-an series and of the adjoining regions of China and Indo-China has suggested that Eastern Burma during the Palæozoic and early Mesozoic had more affinity with the Far-Eastern botanical province than with Gondwana Land. The affinities of the new species are not clear but its geographical position suggests that it will probably turn out to be related to an oriental type rather than to one from the Gondwanas.

The genus *Mesembrioxylon* ranges in age from Jurassic to Recent. The occurrence of *M. shanense* in the Loi-an series does not contradict a Jurassic age suggested for these beds on other grounds.

My thanks are due to Mr. K. N. Kaul, M.Sc., for the photographs and camera-lucida sketches illustrating this paper.

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VIII.—EXPLANATION OF PLATE.

All the figures are untouched photographs. The type specimen and figured sections are preserved at the Geological Survey of India, Calcutta (Registered G. S. I. Type No. 16358).

Mesembrioxylon shanense. sp. nov.

PLATE 31, FIG. 1. Transverse section showing pith with stone cells, endarch protoxylem and wood devoid of growth-rings. (× 35).

FIG. 2. Tangential section showing low medullary rays and resin plates in tracheids. (× 200).

FIG. 3. Radial section through pith and early wood. (× 32).

FIG. 4. Radial section showing bordered pits and resin plates in tracheids. (× *ca.* 600).

FIG. 5. Radial section to show eiporen in medullary ray. (× *ca.* 500).

FIG. 6. Radial section to show structure of pith. (× 121).

SOME FORAMINIFERA FROM INTERTRAPPEAN BEDS NEAR RAJAHMUNDRY.

By S. R. NARAYANA RAO., M.A., AND K. SRIPADA RAO, M.Sc., *Department of Geology, University of Mysore.* (With Plates 32 and 33.)

CONTENTS.

I.—INTRODUCTION.

The material used in the present report was collected from the following localities :—

Pangadi.—A village about eight miles to the west of Rajahmundry. The samples examined consist of :—

1. A blue calcareous marl, occurring as a tolerably persistent seam at the topmost horizon of the inter-trappean series in this region. The bed varies in thickness from a few inches to nearly a foot. It is crowded with marine shells and the finer siftings show calcite casts as well as the actual tests of foraminifera.
2. A compact, hard, fossiliferous limestone which attains a thickness of 12 ft. and probably more. This limestone is rich in foraminiferal and algal remains—the latter represented by three to four genera of the family *Dasycladaceae.*[1] In this compact limestone, the separation of the foraminifera from the matrix is almost impossible and many of the identifications had to be made from thin sections. However, on the weathered surfaces of these limestones, the tests of foraminifera may sometimes be seen protruding and their external characters made out.

[1] Two of these—*Neomeris* and *Acicularia*—are abundant at certain horizons and seem to have contributed materially to the formation of the limestones. A joint paper (J. Pia, S. R. N. Rao and K. S. Rao) describing the Rajahmundry micro-flora will appear elsewhere.

Kateru.—A village on the eastern bank of the Godavari about three miles north of Rajahmundry town. The sample examined consists of a green calcareous mud with abundant remains of *Chara* fruits. The finer washings show occasionally, well-preserved, though very much dwarfed, forms of foraminifera. Many of these forms are identical with those occurring in the Pungadi blue marl. It is evident that the Kateru Chara marl and associated limestones were deposited at the mouth of an estuary, which was in communication with the open sea in which the marine Pungadi limestones were formed.

The Rajahmundry beds must have been deposited during the great marine transgression which, in the words of Dr. C. S. Fox.[1]

'Appears to have attained its maximum extent about the time of the eruption of the basaltic lavas (the Deccan volcanic period) in the Peninsular region of India.'

The marine micro-fauna of Rajahmundry is therefore of more than usual interest and a detailed study may be of considerable help in establishing the stratigraphical relations of these beds with those of other areas of the southern marine province.

The present report has no pretensions to completeness and is intended to serve as a basis for future work. More data have still to be collected before any very satisfactory conclusions can be drawn regarding the age of the deposits or the depths at which they were formed. The fauna, so far identified, without being specially indicative, is not inconsistent with the following general conclusions.

(1) The sea in which the oceanic deposits of the Pungadi area were formed gave place, in its slow regression, to gulf and estuarine conditions. The Pungadi marl (the topmost horizon of the marine inter-trappean series) and the Kateru Chara marl were simultaneously deposited when the estuarine conditions were established. The abundant occurrence of typical pelagic forms like *Orbulina* and *Sphæroidinella* in the lower horizons of the Pungadi limestones, indicates that the physical geography during the Intertrappean period started with marine conditions of moderate depth. The deposits were probably formed very near the land, for there is a complete absence of siliceous remains like those of radiolaria. This, according to Brady[2], is inconsistent with the occurrence of deep oceanic deposits far from land.

[1] *Rec. Geol. Surv. Ind.*, LXIII, p. 187, (1930).
[2] Brady, H. B., *Quart. Journ. Geol. Soc.*, Vol. 48, p. 197, (1892).

Regarding the age of the beds, there are few restricted forms which can be definitely assigned to any horizon. It is however significant that typical Cretaceous forms like *Pseudotextularia*, *Gümbelina* and *Globigerina cretacea* are either very rare or altogether absent. On the other hand forms like *Orbitoidiae* and *Nummulites*, typical of the warm seas of the Eocene age, are also absent. According to data now available, the evidence of the foraminifera seems to be in favour of using the name Palæocene.

We desire to take this opportunity of recording our indebtedness to Mr. F. Chapman, A.L.S., F.R.M.S., Commonwealth Palæontologist of Australia, who kindly checked our identifications. Our thanks are also due to Prof. L. Rama Rao, M.A., F.G.S. Central College, Bangalore, for aid in the preparation of this paper and to the Director, Geological Survey of India, for his kindness in helping us with literature.

II.—DESCRIPTIONS.

FAMILY: *MILIOLIDAE*.[1]

Genus: SIGMOILINA, Schlumberger.

Sigmoilina, several species. Though several species are represented in thin sections of Pungadi limestone, sections satisfactory for a specific determination are not found. G. S. I. No. K 40/248.

Genus: TRILOCULINA, d'Orb.

Triloculina aff. *lævigata*, d'Orb.

(Plate 32, figs. 1 and 9.)

The exterior of the test is composed of but three chambers coiled end to end. Early chambers are quinqueloculine. Length from 0·5 mm. to 0·3 mm. Found in the Pungadi limestones. G. S. I. No. K 40/249.

Family: *LAGENIDAE*.

Genus: ROBULUS, Montfort. (CRISTELLARIA of many authors.)

[1] The classification and naming adopted is that followed by Cushman in his 'Foraminifera—their classification and economic uses, 1933.'

Robulus sp. *indet.*

(Text fig. 1.)

A dwarf form. Test nautiloid, compressed, with well developed keel. Rounded knobs along the periphery. Wall smooth, chambers numerous, costæ and umbonal region rais l, aperture elongate.

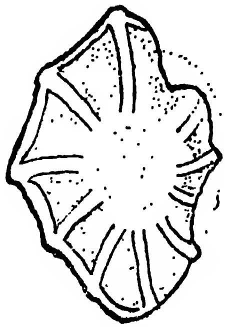

FIG. 1.—*Robulus* sp. *indet.*

Diameter 0·27 mm. *R. fomosus,* figured by Cushman,[1] most nearly resembles our specimen. *R. fomosus* differs in having peripheral spines instead of knobs and being much bigger in size. G. S. I. No. K 40/250.

Robulus cf. *occidentalis.*

(Plate 32, fig. 8, text-fig. 2.)

The keel is thin and transparent. The walls of the chambers are porcellanous. This agrees very closely with *R. occidentalis,*[2] described and figured by Cushman from Jamaica.

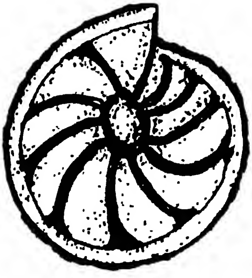

FIG. 2.—*Robulus* cf. *occidentalis.*

[1] Cushman, J. A. & Jarvis, P. W., *Jour. Pal.*, Vol. 4, p. 358, and Pl. 32, fig. 10, (1930).

[2] Cushman, J. A. & Jarvis, P. W., *Jour. Pal.*, Vol. 4, p. 357, (1930).

Both the above species show marked affinities with known Tertiary species. They are found very commonly in the Pungadi marl and Kateru Chara marl. G. S. I. No. K 40/251.

Genus : NODOSARIA.

Nodosaria zippei, Reuss.

(Plate 32, fig. 2.)

A single segment of this species was noticed in one of the sections from the Pungadi limestone. Wall calcareous, tuberculate. Diameter of a segment, 0·3 mm. This species is regarded by Chapman[1] as a restricted form found invariably in the upper Cretaceous. G. S. I. No. K 40/252.

Family : *NONIONIDAE.*

Genus : NONION, Montfort (Syn. NONIONINA, d'Orb.).

Nonion sp. *indet.*

(Plate 32, fig. 5.)

Test nautiloid, bilaterally symmetrical, with numerous chambers Wall perforate. Maximum diameter noticed 0·2 mm. This species appears to be identical with *Nonionina* sp., a Palæocene foraminifera from the Samana Range, figured and described by Lt.-Col. Davies.[2] The Samana fossil is slightly uncoiled which, according to Cushman, is characteristic of the adult form of this genus. G. S. I. No. K 40/253.

Family : *HETEROHELICIDAE.*

Genus : GÜMBELINA, Egger. (TEXTULARIA of some authors).

Gümbelina globifera, Reuss.

(Plate 32, fig. 6.)

Test minute as is the case with this species; tapering, biserial, with round chambers. Length, 0·5 mm. There is a single specimen in our collection. G. S. I. No. K 40/254.

[1] Chapman, F., (1). *Annals of the South African Museum*, Vol. 12, pt. 4, p. 117.
[2] Davies, L. M., *Pal. Ind.*, N. S., Vol. XV, pt. 6, p. 77, Pl. 10, fig. 3, (1930).

Family: *GLOBIGERINIDAE.*

Genus: ORBULINA, d'Orb.

Orbulina cf. *O. universa*, d'Orb.

(Plate 32, fig. 7.)

The test is spherical, with the earlier chambers missing. Diameter of test, 0·3 mm. This specimen resembles *O. universa* described and figured by Galloway and Morrey.[1] Regarding this genus, Galloway[2] writes, "Test spherical in the adult, completely embracing a globigerinoid nucleoconch in the microspheric form which is missing in the megaspheric form, and possibly at other times by resorption". *Orbulina* is a typical pelagic foraminifera and is restricted to Tertiary and later formations. This species is very common in the Pungadi region. G. S. I. No. K 40/255.

Genus: SPHEROIDINELLA, Cushman.

Spheroidinella sp.

(Plate 33, figs. 1 & 2.)

Test ovoid and inflated. Wall hyaline and coarsely perforate. Diameter of test, 0·6 mm. Diameter of pores, 0·02 mm. nearly. This also is a pelagic form quite frequent in the Pungadi limestones. G. S. I. No. K 40/256.

Family: *GLOBOROTALIDAE.*

Genus: GLOBOTRUNCANA, Cushman. (DISCORBINA and ROTALIA of some authors.)

Globotruncana sp.

(Plate 33, figs. 11 & 12.)

Chambers globose, and cancellated. Much eroded fragments of these were noticed and a specific determination is not possible. G. S. I. No. K 40/257.

[1] Galloway, J. J. & Margaret Morrey., *Jour. Pal.*, Vol. 5, No. 4, p. 349, Pl. 40, fig. 1, (1931).
[2] Galloway, J. J., A manual of Foraminifera, p. 333, (1933).

Genus : GLOBOROTALIA, Cushman.

Globorotalia cf. *G. menardii*, d'Orb.[1]

(Plate 32, fig. 4.)

Dorsal side of the test is strongly convex while the ventral side is slightly concave. Peripheral margin thin, wall calcareous and perforate. The tests are minute and more than one species is represented in the finer washings of the Pungadi and Kateru marls. G. S. I. No. K 40/258.

Family : *ANOMALINIDAE*.

Genus : *Anomalina*.

Anomalina rudio, Reuss.

(Plate 32, fig. 3.)

Test much compressed with numerous chambers. This is a shallow water species restricted to the higher levels of the Pungadi limestones. G. S. I. No. K 40/259.

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[1] Cushman, J. A., *Geol. Surv. Florida*, Bull. No. 4, Pl. 12, fig. 1, (1930).

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IV.—EXPLANATION OF PLATES.

PLATE 32, FIG. 1. *Triloculina* aff. *lævigata.* × 100. G. S. I. No. K 40/249.

FIG. 2. *Nodosaria zippei,* a single segment. × 100. G. S. I. No. K 40/252.

FIG. 3. *Anomalina rudio* Reuss. × 50. G. S. I. No. K 40/259.

FIG. 4. *Globorotalia* cf. *G. Menardii,* d'Orb. × 100. G. S. I. No. K 40/258.

FIG. 5. *Nonion* sp. ind. × 120. G. S. I. No. K 40/253.

FIG. 6. *Gümbelina globifera,* Reuss. × 150. G. S. I. No. K 40/254.

FIG. 7. *Orbulina* cf. *O. universa.* × 100. G. S. I. No. K 40/255.

FIG. 8. *Robulus* cf. *R. occidentalis,* by reflected light. × 80. G. S. I. No. K 40/251.

FIG. 9. *Triloculina* aff. *lævigata,* by reflected light. × 60. G. S. I. No. K 40/249.

PLATE 33, FIG. 1. A section of Pungadi limestone showing *Spheroidinella* sp., *Globotruncana* sp., and fragments of calcareous alga, *Acicularia.* × 80. G. S. I. No. K 40/256.

FIG. 2. A section of Pungadi limestone showing *Spheroidinella* sp., *Globotruncana* sp., and the calcareous algæ *Neomeris* and *Acicularia.* × 50. G. S. I. No. K 40/257.

Holosporella cf. *H. siamensis*, PIA, FROM THE RAJAHMUNDRY LIMESTONES.

BY S. R. NARAYANA RAO, M. A., AND K. SRIPADA RAO, M. SC., *Department of Geology, University of Mysore.*

Holosporella, a name introduced by Dr. Julius Pia[1] for a new genus of calcareous alga of the family *Dasycladaceae*, hitherto known from a single locality, has recently been found in the limestones associated with the Rajahmundry volcanics (Deccan trap series) near Pungadi (17° 01′ : 81° 39′)—a village about 8 miles to the west of Rajahmundry town.

Holosporella siamensis, Pia., the original species on which the genus is founded, was figured and described by Dr. J. Pia in 1930, from the Kamawkala limestone (Upper Triassic) collected from the Burmo-Siamese frontier. He described the Siamese fossil as a "sporangial tube of a *Dasycladaceae* otherwise devoid of calcification." The sporangial cylinder in this genus, is, according to him, formed of sporangia situated in the axial cell of the alga and hence its description as an 'endospore' *Dasycladaceae*. The presence of an axial perforation distinguishes this new genus from *Acicudella* and *Acicularia*, while the absence of the calcareous skeleton or casing distinguishes it from *Diplopora*. An 'endospore' axial cell is considered to be a primitive character found more commonly in the Palæozoic and Mesozoic genera.

A noteworthy feature of the Triassic *Dasycladaceae* is their limited vertical range. Species appear to have changed with great rapidity. The unexpected find, therefore, of a Triassic species in beds as high as the Deccan volcanic period is of considerable interest.

The matrix in which the present specimen is imbedded is an extremely hard, compact limestone. Foraminifera and calcareous algæ, chiefly *Neomeris* and *Acicularia*, have contributed in no small measure to the formation of this limestone. *Holosporella* is very rare and even then represented by a few small fragments. We may

[1] *Rec. Geol. Surv. Ind.*, LXIII, pp. 177-181, (1930).

probably account for the rarity of this genus in a fossil condition to the absence of a protective casing of lime, which is well developed in some forms like *Neomeris* and *Diplopora*, enormously increasing their chance of preservation.

The following description is based on slide G. S. I. No. K 40/260.

Description.

Holosporella cf. *siamensis.*

Thallus cylindrical with a relatively broad axial tube. Wall fairly thick with a single row of spherical sporangia. The calcareous matter filling the cavity is crystalline, while the sporangial cavities are filled with a dark opaque matter probably carbonaceous in character.[1]

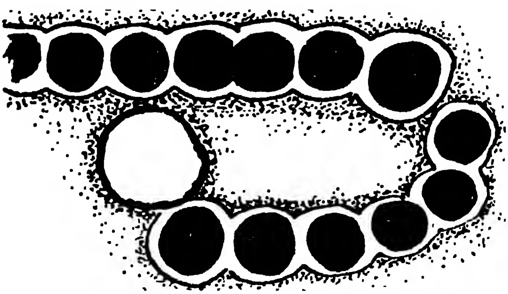

FIG. 1.—*Holosporella* cf. *siamensis*.

Measurements.

	Holosporella from Rajahmundry.	*Holosporella siamensis.*
Outer diameter of cylinder	about 0·51mm.	about 0·4mm.
Diameter of central perforation . .	about 0·21mm.	about 0·15mm.
Diameter of globules	0·12—0·15mm.	about 0·21mm.
Thickness of membrane	about 0·01mm.	about 0·01mm.

[1] Pia, J., *Jour. Pal.*, Vol. 10, p. 6, (1936).

Remarks.—In its perforated thallus and the absence of the outer skeleton encasing the axial cell, the Rajahmundry fossil agrees with Dr. Pia's definition of the genus *Holosporella.* In general appearance and dimensions, it appears to be specifically identical with the Siamese fossil. Dr. Pia, who has examined our specimen, while confirming the identification, was kind enough to supply the following valuable and interesting notes :—

'I am not able to find out any essential difference between your fossil and my *H. siamensis* from the Upper Triassic of the Burmo-Siamese frontier. The measurements are well within the probable variability of one and the same species.

This occurrence is obviously most perplexing. A Triassic age of the Inter-trappean beds is, of course, out of the question, not only for geological reasons, but also on account of the algal genera *Acicularia* and *Neomeris* found in them. On the other hand, the proofs given for the inclusion of the Kamawkala limestones from the Burmo-Siamese boundary with the Upper Triassic (Gregory, 1930, and the following papers in the same volume) seem to be convincing enough. It would, however, be against all our experience to suppose that a species of the *Dasycladaceae* did survive from the Triassic into the Tertiary or even into the Upper Cretaceous time.

Two other explanations will have to be kept in mind. It may be that the geological structure of the limestones near the Thaungym river is much more complex than we suppose. On the other hand the genus *Holosporella* does not yield as many clear characters for the definition of a species as *Dasycladaceae*, with a more complete calcification of the thallus, do. Similar sporangial cylinders may have been formed in the axial cells of algæ very different with respect to the structure of the branches. To make a choice between these two possibilities we have to await further discoveries. In any case the existence of an endospore *Dasycladaceae* in so high a geological horizon is quite unexpected a fact and probably a new instance of the survival of primitive forms in tropical regions.'

It may however be mentioned that this is not the first instance of such a record in India, as far as fossil algæ are concerned, for Dr. Walton[1] has described *Triploporella*, originally regarded as an extinct Cretaceous alga,[2] from the Ranikot beds (Lower Eocene) of Sind. G. S. I. No. K40/260.

Literature cited.

(1) Pia, J.,—A new *Dasycladaceae Holosporella siamensis*, nov. gen., nov. sp., with a description of the allied genus *Aciculella* Pia. *Rec Geol. Surv. Ind.*, 63, pp. 177-181, (1930).

[1] Walton, J., *Rec. Geol. Surv. Ind.*, LVI, pp. 213-219, (1924).
[2] Seward, A. C., Plant life through the ages, p. 423, (1933).

(2) Pia, J.,—Calcareous algæ from the Upper Cretaceous of Tripoli (North Africa). *Jour. Pal.*, Vol. 10, p. 6, (1936).

(3) Walton J.,—On a calcareous algae belonging to the *Triploporelleae* (*Dasycladaceae*) from the Tertiary of India. *Rec. Geol. Surv. Ind.*, 56, pp. 213-219, (1924).

(4) Seward A. C.,—Plant life through the ages, p. 423, (1933).

A NOTE ON THE MALERI BEDS OF HYDERABAD STATE (DECCAN) AND THE TIKI BEDS OF SOUTH REWA. BY N. K. N. AIYENGAR, M. A., *Field Collector, Geological Survey of India.* (With Plate 34.)

Among the Gondwana rocks of India, the three chief places where Triassic reptilian fossils occur are, (1) near Deoli in the Panchet rocks, Raniganj coalfield, (2) around Maleri in the Pranhita-Godavery valley, Hyderabad State, and (3) at Tiki in south Rewa.

The writer was deputed to collect reptilian fossils near Tiki in 1929-30 and 1935, and Maleri in 1935. As these localities were not easily accessible, few geologists have visited them in recent times.

(1) Deoli.

The presence of Triassic reptilian fossils has already been recorded in the Panchet beds of the Raniganj coalfield. They occur chiefly

'Just[1] North of the village of Deoli, near Bakúlia, and about quarter of a ile East of the mouth of the Besram stream, a considerable expanse of rocks is xposed in the bed of the Damúda, South of the channel occupied by the water the dry season, and here a bone bed was found, containing detached, and, frequently, rolled bones, vertebræ, and fragments of jaws with teeth; they are not ery abundant, but a considerable number were procured. Some were also found another spot in the Damuda, a little East of the village of Dikha and fragments bone were occasionally met with in other localities.'

The fossils from these beds have been described by Thomas Huxley[2] and W. T. Blanford[3]. The latest account of these Panchet beds is to be found in Mr. E. R. Gee's memoir on the Raniganj coalfield.[4]

(2) Maleri.

Maleri (Marweli of the map, sheet 56 M/12; 19° 11′ : 79° 36′) is a village ten miles E. N. E. of Rechni Road railway station on

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 129, (1861).
[2] *Quart. Journ. Geol. Soc.*, XVII, Pt. 1, p. 362, (1861). *Pal. Ind.*, Ser. IV, Vol. I, Pt. 1, (1865).
[3] *Pal. Ind.*, Ser. IV, Vol. I, Pt. I, p. 25, (1865).
[4] *Mem. Geol. Surv. Ind.*, LXI, pp. 54-59, (1932).

the Kazipet-Balharshah section of H. E. H. the Nizam's State Railway in the Asafabad district of Hyderabad.

Though the earliest geological work in this area began as long ago as 1833, definite geological and palæontological work of interest was first commenced by the Rev. S. Hislop[1] in 1856. Later investigators were T. Oldham[2], W. T. Blanford[3], T. W. H. Hughes[4], R. Lydekker[5] and W. King[6].

The writer's work was chiefly confined to the central part of the Maleri formation around Maleri itself, though he traversed some parts in the southern area as well. The present description refers mainly to the country in the neighbourhood of Maleri.

Lithology.

The country near Maleri is slightly undulating, with a few shallow streams. The land is covered either with black cotton soil or Maleri red clays. In some places chipped rocks (Palæolithic flints) are found. As in the case of the Tiki formation, which will be described later, in the Maleri beds sandstones are subordinate to clays. A good and complete section of the rocks of the Maleri formation is not seen near Maleri itself, but after examination of some of the exposures south-west of Maleri and at the water gate of Rampur village (Pl. 34, fig. 1), the writer thinks that the following generalised section will give an idea of the probable stratigraphy of the formation near Maleri :—

	Feet.
Black cotton soil	2—4
Sandstone boulder bed	2
White or light grey, felspathic, occasionally calcareous, sandstone. (In some places this sandstone is considerably decomposed and mixed with much *kankar*)	4—7
Nodular, cherty looking, calcareous rock (seen south-west of Maleri)	5
Fine grained thinly laminated, grey calcareous sandstone, showing false bedding	5
Coarse rubbly calcareous sandstone. (This bed has yielded reptilian fossils in certain places)	2—3
Red clay,—thickness not known.	

[1] *Quart. Journ. Geol. Soc., London,* XVII, p. 348, 1861, XX, p. 280, (1864). *Journ. Bombay Br. R. A. S.*, Vol. VI, p. 202, (1861).

[2] *Mem. Geol. Surv. Ind.*, I, pp. 295-309, (1859).

[3] *Mem. Geol. Surv. Ind.*, IX, pp. 295-330, (1872), Pal. Ind. Ser., iv, Vol. 1, Pt. 2, pp. 17-23, (1878).

[4] *Rec. Geol. Surv. Ind.*, IX, p. 86, (1876).

[5] *Pal. Ind. Ser.*, IV, Vol. I, Pt. 5, (1885).

[6] *Mem. Geol. Surv. Ind.*, XVIII, Pt. 3, pp. 118-123, (1881).

Owing to their softness, the red clays do not show any bedding, but the rubbly sandstone bed immediately overlying them shows a dip of 10°-12° in a north-east or N. N. E. direction.

Though the Maleri formation extends from Sandgaom (19° 35′ : 79° 42′) to Semnapali (18° 42′ : 79° 54′), a distance of about 60 miles, reptilian fossils have been found only in the central part of this area, that is, between Maleri and Nannial (19° 4′ : 79° 38′), and in the Angrezapalli (18° 48′ : 79° 47′) outlier. The reason for this appears to be that the beds containing fossils have been well exposed in these places owing to the gentle dip, which has allowed rapid weathering of the rocks, and has also prevented the fossils so exposed from being washed away by rains. Such is the country bounded by the villages, Teklapalli (19° 8′ : 79° 35′), Nannial (19° 4′ : 79° 38′), Kanepalli (19° 9′ : 79° 40′), Venkatapur (19° 11′ : 79° 38′), Bhimni (19° 12′ : 79° 38′) and Achlapur (19° 10′ : 79° 32′).

Fossil collection.

Owing to the flatness of the country and constant cultivation, fossils are sparsely distributed. One of the best methods adopted by previous workers like Hislop and Hughes for collecting fossils in this area which met with much success, was by "beating" (Pl. 34, fig. 2). In making further collections, the same method was followed by the writer, whose provisional identifications of the fossil collections from Maleri are as follows :—

(1) One mile north-east of Maleri in the stream exposures.

Hyperodapedon huxleyi, Lyd.—Maxilla, dentary bones and scutes.

Parasuchus sp.—Teeth, vertebræ and imperfect limb bones.

Belodon sp.—Limb bones.

Unio sp.—

(2) Half a mile north of Maleri in the black soil.

Hyperodapedon sp.—Vertebræ and bones.

Labyrinthodont.—Dentary bones.

Unio sp.—

(3) One mile north-west of Maleri in the red clay.

Hyperodapedon sp.—Maxillæ.

Unio sp.—

(4) One mile south-west of Maleri.

Large limb bones, vertebræ, scutes, maxillary and dentary fragments, probably belonging to *Belodon*. All these specimens

were collected at one spot, and they may belong to the same individual.

(5) About five furlongs north of the last mentioned locality, were found two large ? Dinosaurian vertebræ and two or three species of the fish *Ceratodus*. In addition to these fossils, coprolites are abundant about half a mile W. S. W. of Maleri. They are generally greenish yellow in colour varying in size from that of a walnut to a cocoanut. In shape some are flat and cake-like, some cylindrical, spiral, reniform or botryoidal. In cross section they present a central core surrounded by layers of iron-impregnated material. The nature of the material of these coprolites collected has not yet been examined.

(6) One mile E. S. E. of Achlapur.

Hyperodapedon sp.—Bones, imperfect maxillæ.

Unio sp.—

(7) Half a mile north of Rechni village.

Remains of *Hyperodapedon* sp. and *Unio* sp.; the latter are much smaller in size than those found at Maleri.

(3) Tiki.

Tiki (81° 22′ : 23° 56′) sheet 64 E/5, is a small village about seven miles south of Beohari, and about fifty miles north-east of the Umaria coalfield in south Rewa. The best route to this locality is *viâ* Sutna and Rewa.

Previous observers.

Reptilian fossils were first noticed near Tiki by T. W. H. Hughes about the year 1879, during the course of his survey of the south Rewa Gondwana basin[1]. The collection made by him in this area has been described by Lydekker[2]. Dr. G. de P. Cotter,[3] who visited this place during the year 1916 to investigate the relationship of the Tiki beds with the Parsora formation, also collected some reptilian remains near Tiki.

Topography.

Like most Gondwana areas, the country around Tiki is slightly undulating. The softer red clays and sandstones have been much denuded. Wherever harder rocks like the ferruginous sandstones of the upper division

[1] *Rec. Geol. Surv. Ind.*, XIV, Pt. 1, p. 136, (1881).
[2] *Pal. Ind.*, Ser. IV, Vol. I, Pt. 5, (1885).
[3] *Rec. Geol. Surv. Ind.*, XLVIII, Pt. 1, p. 27, (1917).

protect the clays below, they give rise to flat-topped hills, like the Hartala and Beohari hills.

Lithology.

As already mentioned the rocks can be divided into two distinct lithological divisions. The upper division is chiefly composed of hard ferruginous sandstones with rounded pebbles at the top. These beds overlie fine-grained grey hard sandstones with red laminations, and some purple shales. Some good varieties of such rocks are quarried near Beohari for building purposes. So far no fossils, either plant or animal, which would help in determining their age, have been found in these rocks. They may represent the upper division of the Tiki beds or may be younger than the latter. The lower division, known as the Tiki stage, in which reptilian fossils, fossil wood, and fresh-water shells like *Unio* occur, is made up mostly of red and green clays with subordinate sandstones. These sandstones are often calcareous. Fine green laminations and green clay galls are very characteristic of these sandstones, and in some places the calcareous matter segregates on the surface of the sandstones near Tiki and forms a thick vermicular encrustation on them. False bedding is very common, and calcified or carbonised fossil wood is sometimes found. The red clays, being softer and more easily denuded, form the lower ground. They are full of yellow *kankar*. The red clays make their first appearance in the Son River section a mile up the stream from Giar. The following section, which is seen on the right bank of the Son at Giar (23° 30′ : 81° 19′), may be taken as a type one for the Tiki beds :—

	Feet.
Siliceous sandstones, grey and brown in colour with decomposed felspars and clay galls	15
Fine-grained grey sandstones with interrupted green laminations, false-bedded, and containing partly carbonised and calcified fossil wood	5
Weathered calcareous rubbly grey sandstone	2
Fine-grained sandstone	2
Bright red clays,—thickness not known.	

This section has also been noticed by Hughes.

Though the red clays are found to cover a considerable area, fossils have been found only in those south of Tiki. In this locality reptilian and molluscan fossils are found on the much denuded clays. Most of the fossils are covered with calcareous matter and are much worn. Not a single fossil was seen *in situ*. It is not

definitely known from which beds these fossils are derived, but some fragments of fossils were enclosed in a rubbly calcareous matrix which occurs above the red clays. The writer, however, noticed in the Godavery area that fossils were present in such calcareous sandstones. The following fossils were found in the collection made near Tiki :—

Hyperodapedon huxleyi, Lyd.—Fragmentary palato-maxillæ, dentary bones, vertebræ, etc.

?*Dinosaurian*.—Tooth.

Belodon sp.—Fragmentary maxilla, vertebra and teeth.

Parasuchus sp.—Limb bones, scutes and teeth.

An interesting frontal part of the internal cast of a saurian skull was also collected.

Unio sp.—

(Fish teeth, which are fairly common in the Maleri area, have not been found at Tiki.)

EXPLANATION OF PLATE.

PLATE 34, FIG. 1.—Exposure of Maleri beds at Rampur near Maleri.

FIG. 2.—Searching for reptilian fossils at Maleri, Hyderabad State.

THE STRUCTURE OF THE HIMALAYA IN GARHWAL. BY J. B. AUDEN, M. A., F. G. S., *Geologist, Geological Survey of India.* (With Plates 35 to 37.)

CONTENTS.

I.—INTRODUCTION.

The object of this paper is to summarise my present views on the structure of the outer Himalaya between the Jumna River and Lansdowne, as well as to introduce a preliminary interpretation of a profile across the Garhwal Himalaya from the Plains to the Main Himalayan Range. I shall not discuss lithology, or the stratigraphical relationships of the various rock groups. That will be reserved for a Memoir which it is hoped to write shortly.

At intervals during the last eight years it has been my duty to make a detailed survey of the lower Himalaya, working south-eastwards from Lat. 31°N. : Long. 77°E. to Lat. 30°N. : Long.

78° 30′ E. The region with which this paper is chiefly concerned lies east of Long. 78°E. and is about 1,500 square miles in area. In addition traverses have been made to the snowy ranges up the Alaknanda and Bhagirathi branches of the Ganges river. The whole region is included within Survey of India map No. 53, on the scale of 1 : 1,000,000; see Plate 36.

1. Historical.

In 1864 H. B. Medlicott published the first connected account of the geology of the lower Himalaya[1]. The area he described is about 7,000 sq. miles and lies for the most part west of the Tons river, centering around Simla. Important though this memoir is, it has little direct bearing on the region east of Long. 78°. Moreover, Medlicott's work has already been discussed by G. E. Pilgrim and W. D. West[2] and later to some extent by myself[3], so that it can be omitted from the discussion which follows.

Between 1885 and 1890 C. S. Middlemiss carried out detailed surveys in three areas of the Kumaon Division :—

(1) along the outer Himalaya between the Ganges river and Gungti hill (29° 45′ : 78° 55′)[4];

(2) around Dudatoli mountain (30° 03′ : 79° 12′)[5];

(3) the Siwalik ranges from the Ganges to the Nepalese frontier[6].

It is with the first area that we are most directly concerned, since it overlaps that in which I have worked and since it afforded indications of enormous tectonic movements in the Himalaya.

In 1891 C. L. Griesbach published a Memoir on his survey within, and north of, the Main Himalayan Range[7].

Between 1883 and 1888 R. D. Oldham published accounts of his mapping in the Chakrata Tahsil of Dehra Dun district and in regions to the west of the Tons river[8]. He was unfortunate in working on an isolated area of exceptional geological complexity,

[1] *Mem. Geol. Surv. Ind.*, III, (1864).
[2] *Op. cit.*, LIII, (1928).
[3] *Rec. Geol. Surv. Ind.*, LXVII, p. 357, (1934).
[4] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).
[5] *Op. cit.*, p. 134, (1887).
[6] *Mem. Geol. Surv. Ind.*, XXIV, (1890).
[7] *Op. cit.*, XXIII, (1891).
[8] *Rec. Geol. Surv. Ind.*, XVI, p. 193, (1883); XXI, p. 130, (1888).

the southern part of which even now, after a fuller survey of the surrounding regions, has not yielded any satisfactory solution of structure.

After an interval of forty years, detailed mapping was begun in the Simla area by Pilgrim and West, who demonstrated for the first time in that part of the Himalaya the existence of great overthrusts[1]. I was attached to the Himalayan party in 1928, and, working to the south-east from Subathu, have joined up with the area already mapped by Middlemiss south-east of the Ganges river. A paper of mine on the Geology of the Krol Belt was published in 1934 in which the portion of the outer Himalaya between longitudes 77° and 78° was described[2]. A further paper was published in 1935 describing traverses carried out in the Karakoram, Garhwal, eastern Nepal and Sikkim[3].

2. Topographical and Geological Zones in the Garhwal Himalaya.

Before describing the tectonics of the Garhwal Himalaya in greater detail, a brief mention may be made of the zones into which it can be divided. Topographically the following zones may be distinguished :—

1. Siwalik Range and Dun.

2(*a*). Outer lower Himalaya, with an intricate network of spurs and rivers.

(*b*). Inner lower Himalaya, with simpler topography.

3. Main Himalayan Range, with steep scarp slopes facing towards the Plains, and gentler dip slopes facing Tibet.

4. High peaks north of the Main Himalayan Range with irregular disposition.

The structural units do not fit into this topographical classification, since, in some parts at least, three structural units are superimposed one upon the other. The main tectonic divisions for the Garhwal Himalaya are as follows :—

(1) Autochthonous unit. The base of this unit is probably the Simla slate series, overlying which occur Nummulitics.

[1] *Mem. Geol. Surv. Ind.*, LIII, (1928).
[2] *Rec. Geol. Surv. Ind.*, LXVII, p. 357, (1934).
[3] *Op. cit.*, LXIX, p. 123, (1935).

Murrees and Siwaliks. Thrusts occur within this unit, but do not seem to be of premier magnitude. The most important thrust is that which has long been called the Main Boundary Fault. This Autochthonous unit appears to occur well within the Himalaya, some twenty miles at least from the Dun.

(2) The Krol Nappe, thrust upon the Autochthonous unit, and corresponding to the Krol Belt described in a previous paper of mine.

(3) The Garhwal Nappes, thrust upon the Krol Nappe. The main Garhwal Nappe may root in the Main Himalayan Range.

(4) The Main Himalayan Range, which appears to be made up partly of elements common to one of the Garhwal Nappes and partly of a distinct group of para-gneisses and schists.

(5) The granite zone to the north of the Main Himalayan Range, containing granites intrusive into the southern para-gneisses and schists.

(6) The Tethys zone of fossiliferous sediments. The relationship of this zone to the granites and para-gneisses is at present obscure. From the work of Hayden in Spiti it would appear that the gneissic granite, which may be Permian or Tertiary in age, has an intrusive contact with the Cambrian. The recent work of Professor Arnold Heim and Dr. Gansser may clear up this question.

The greater part of this paper will be devoted to a discussion of the Autochthonous, Krol and Garhwal units occurring in the outer lower Himalaya. Before examining the results of recent work, it is necessary to summarise the interpretation given by Middlemiss to the outer lower Himalaya south-east of the Ganges river.

II.—MIDDLEMISS, 1887.

In 1887 Middlemiss published his important paper on the Physical Geology of West British Garhwal[1]. This was followed

[1] *Rec. Geol. Surv. Ind.*, XX, p. 33, (1887).

by a memoir on the Siwalik rocks in 1890[1]. The earlier work appears to have been carried out within two seasons, and one is amazed at the extent of ground covered and the general accuracy of the mapping. The only complaint is that, in a region offering so many problems, Middlemiss should intentionally have omitted elucidation of all except the most pressing one. The succession as determined by him is given below :—

——	Sub-Himalayan (Siwalik).
Outer Formation . .	Nummulitic. Tal. Massive Limestone. Purple Slates. Volcanic Breccia.
Inner Formation . . .	Schistose series with intrusive gneissic granite.

Middlemiss found that the schistose series occurred in an outcrop enclosed by, and apparently overlying, rocks of the Outer Formation. Almost all his discussion is confined to this relationship. His argument is summarised below.

The sequence of the rocks of the Outer Formation is a normal one, and is established by the presence in it of two fossiliferous horizons, Nummulitic and Tal limestone, the Nummulitic being the youngest and on top. The disposition of the Inner Schistose series in relation to this normally lying Outer Formation is best given in his own words[2] :—

'....at every point round the schistose area the Outer formations appear to dip towards and under the schistose series at steep angles (50°-60° generally); whilst the schistose series itself is disposed apparently in the form of an elongated quaquaversal synclinal upon the top of the Outer formations, and culminates in a capping of gneissose rock on the summit of Kalogarhi mountain.....

In other words, the observer after a hasty examination is almost driven to the conclusion that there is an upper metamorphic series lying normally upon the comparatively unmetamorphosed zone of Outer formations (a counterpart of the opinion long held with regard to the strata of the Scotch Highlands)'.

Again, on page 36, after commenting on the rocks of the Outer Formation being in their natural order (which is not true over

[1] *Mem. Geol. Surv. Ind.*, XXIV, (1890).
[2] *Rec. Geol. Surv. Ind.*, XX, p. 34, (1887).

part of the area) and dipping inwards towards the schistose rocks, he remarks :—

'One seems almost driven to conclude that if a boring were sunk through the centre of the schistose area, we should inevitably strike the Tal beds below'.

Middlemiss then attempts to prove that this conclusion would be wrong, claiming that the facts

'not only render the above interpretation unacceptable, but emphatically negative it'.

Firstly, he states on page 37 that if the Tal beds in reality continue below the schistose series, it follows that the Nummulitics, where present, must do the same :—

'that is to say, a soft, shaly, tertiary rock, not only must lie as a foundation on which the schists are piled, but also must be beneath them in direct contact'.

Such a case of selective metamorphism is ruled out as impossible, from which Middlemiss concluded that the schistose series must be older than the Nummulitics.

Secondly, having established that the schistose rocks are older than the Nummulitics, he argues that they must have been moved by reversed faulting against the Nummulitics. The argument on page 38 is a little involved, but the conclusion is that a combination of the 'sigma-flexure' with a reversed thrust plane is sufficient to explain the relative positions of the Outer and Inner Formations.

This same argument is repeated in *Memoirs, Geological Survey of India*, 24, pp. 73-77, (1890), namely that the Nummulitics must be younger than the schistose series, and that the rocks of the Outer Formation are separated from the overlying schistose series by a reversed fault. On page 74 of this memoir the fault is stated to dip in one place at about 25° northwards, as is also shown in Section VI.

It is necessary, therefore, on this thesis, to imagine a reversed fault, of ring shape, everywhere dipping inwards centripetally below the schistose series.

The argument of Middlemiss is weak, because it does not succeed in proving, as he imagined, that the schistose series cannot completely overlie the Nummulitics and Tals. It only indicates that the schistose series are older than the Nummulitics and that their

position with respect to the Nummulitics cannot be a normal stratigraphical one. It suggests nothing about the nature of the dislocation which has caused the Nummulitics and schistose series to be brought together by an abnormal contact. Middlemiss chose to assume a ring-shaped reversed fault and therefore an essentially autochthonous disposition, but did not consider the possibility of a great overthrust bringing the schists and slates to overlie completely the Nummulitics and Tals. He refers to the Scottish Highlands (pp. 33, 34), and specifically mentions the solution to the problem there by Peach and Horne, but considered that the Garhwal area examined on its own merits did not warrant a similar explanation. I hope to show later that the evidence does in fact point to the conception of a great overthrust.

The problem remained as Middlemiss left it for exactly fifty years. His map has been reproduced in both editions of 'A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet' and in Wadia's 'Geology of India', but no attempt has been made in these publications to discuss the difficulties of structure implied by accepting the interpretation which Middlemiss adopted. His account was, however, read independently by Mr. West and myself, both of us feeling the excitement of the possibility of nappe structures latent in it.

III.—RECENT SURVEY, 1935-36.

During the last three seasons I have mapped east of Longitude 78°E. and have joined up the succession which I had established around Solon (described in 1934) with that of Middlemiss. Before reaching the Ganges river, I found both in 1935 and in 1936 structures in Tehri Garhwal which seemed to me to settle the validity of Middlemiss' condemned impression. Now, having examined part of the Garhwal area, some of it in detail, I am convinced of the existence of great overthrusts. There are, it is true, many difficulties involved in a region almost devoid of fossiliferous rocks, except the Tal limestone, (the fossils in which are so broken that no certain age has been assigned to them) and the Nummulitics, and in which there appear to be recurrences of rock types throughout the assumed stratigraphical succession. Yet some of the features seem clear and worth recording apart from those that are less explicable.

The following tables give the stratigraphical and tectonic successions which I have determined east of Longitude 78°. To the second table has been added the succession found by Middlemiss in Garhwal in 1887 :—

Succession east of Longitude 78°E.

Formations.	Unconformities.	Approximate Maximum Thickness.	Probable age.
Siwalik	..	16,000	Upper Miocene to Pleistocene.
	—— ? ——		
Murree (almost absent east of Long. 78°)	..	?	Lower Miocene.
	—— ? ——		
Nummulitic	..	?	Eocene.
	——~~~~——		
Tal limestone and Calc grit	..	200	Upper Cretaceous ?
	——~~~——		
Tal: Upper Tal quartzites	..	4,500	Cretaceous } ?
Tal: Lower Tal shales	..	2,000	Jurassic } ?
	——~~~——		
Krol: Upper Krol dolomites, limestones and shales.	..	3,000	Trias } ?
Krol: Krol red shales	..	1,000 (Krol red shales and Lower Krol limestones and shales)	Permian } ?
Krol: Lower Krol limestones and shales	..		
	————		
Blaini: Infra Krol slates	..	2,000 (Blaini)	? Talchir (Uralian).
Blaini: Upper Blaini boulder bed and dolomite.	..		
	——~~~——		
Blaini: Blaini slates	..		
Blaini: Lower Blaini boulder bed	.		
	——~~~——		
Nagthat	..	3,000	Devonian ?
	——~~~——		
Chandpur	..	4,000?	Lower Palæozoic and pre-Cambrian?
Simla slates, possibly equivalent to the Chandpur series although different in lithology.	..	..	
Dolerites	..	..	Late Tertiary.

Note.

—— = Conformity.

——~~~—— = Unconformity.

Tectonic Succession in Tehri Garhwal and British Garhwal.

—	Tehri Garhwal and British Garhwal.	British Garhwal, Middlemiss, 1887.
Garhwal Nappes .	Chandpur (metamorphosed). —— *thrust* —— Nagthat, Chandpur } (little metamorphosed). Boulder beds, slates and limestones of uncertain stratigraphical horizon occur in one outlier below metamorphosed Chandpurs.	Inner Schistose series.
—— *Garhwal Thrust* ——		—— *reversed fault* ——
Krol Nappe . .	Nummulitic . . . . . Tal . . . . Krol. . . . . . . Blaini . . . . . . Nagthat, Chandpur } metamorphosed and unmetamorphosed.	Nummulitic. Tal. Massive Limestone. Volcanic Breccia in an undifferentiated group of Purple Slates
—— *Krol Thrust* ——		
Autochthonous . . .	Dagshai, Nummulitic Siwalik Simla slates.	

I. Autochthonous.

1. SIWALIKS.

The structure of the Siwaliks east of the Ganges has already been described by Middlemiss, whose illustrative sections are classics in Indian geological literature. Between the Jumna and Ganges rivers the main structure is an anticline in the Siwalik Range (the axis of which is slightly oblique to the topographical alignment of the range), a syncline forming the Dun valley, and to the north-east an overturned anticline which is truncated on the north side by the Main Boundary Fault and the Krol Thrust. The base of the Siwaliks is nowhere seen, but it is presumed that it

consists of Nummulitics with attenuated Dagshai rocks resting on Simla slates; Section 1, Plate 37.

2. DAGSHAI AND NUMMULITICS.

The Main Boundary Fault, in the sense originally used by Medlicott, separates the Siwaliks from the older Tertiaries which have been thrust upon them. East of Long. 78° the Dagshai rocks (Murrees) are very seldom seen, and the chief fault is the Krol thrust which has brought pre-Tertiaries forward so as to rest directly on Siwaliks. This Krol Thrust has been called the Main Boundary Fault both by Middlemiss and myself, but, although it does in fact form the northern boundary of the Siwaliks over some of the area between Dehra and Naini Tal, it is not the same fault as that to which Medlicott originally assigned the term[1].

In the neighbourhood of Solon and Subathu, Dagshai and Subathu rocks (Murree and Nummulitic) rest upon Simla slates and have been overthrust by the rocks of the Krol Nappe. This is well seen around the north-west end of Pachmunda Hill and along the Blaini river[2].

Dagshai rocks are seen along the Tons river by Kalawar (30° 32′ : 77° 49′), on the left bank of the Amlawa river at Kalsi, and as a very narrow outcrop running in a south-east direction to about Long. 78° 02½′. They are thrust by a steep reversed fault (Main Boundary) upon Nahan rocks and are themselves overthrust at a gentler angle by pre-Tertiaries (Krol Thrust). Lenticles of fossiliferous limestone in the Dagshai rocks of the Tons river suggest that Nummulitics may be present there as well.

Between Dehra and Rikhikesh, Nummulitics together with cindery nodular sandstones, which are probably Dagshai, rest upon Simla slates and have been overthrust by the rocks of the Krol Nappe. They occur in two windows which will be described in greater detail in the next section. Probable Tal rocks occur, though poorly exposed, in the Chandna Rao at 30° 10′ : 78° 15′ evidently to the south-west of the Krol Thrust and belonging to the same tectonic horizon as the complex Nummulitic and Tal association of Banas Talla and Banas Malla (29° 57′ : 78° 21′).

[1] Middlemiss, C. S., *Mem. Geol. Surv. Ind.*, XXIV, pp. 19, 31, (1890); *Mem. Geol. Surv. Ind.*, XXXVIII, p. 337, (1908).
Auden, J. B., *Rec. Geol. Surv. Ind.*, LXVII, p. 431, (1934).
[2] *Rec. Geol. Surv. Ind.*, LXVII, p. 436, (1934).

Within the Himalaya, Nummulitics are seen resting upon Simla slates at Sayasu (30° 42′ : 77° 44′), and from just north of Dabra (30° 40′ : 77° 49′) down to the Tons river. In the Tons river Dagshai rocks are almost certainly present in addition to the Nummulitics.

Numerous faults and thrusts occur in the rocks of this zone. It is possible also that the Tertiaries may have been pushed bodily over the Simla slate foundation, with the Nummulitics acting as a lubricating horizon, in a manner comparable to the anhydrite horizon at the base of the Mesozoic succession of the Jura Mountains. These movements are probably, however, of less magnitude than those involved in the Krol and Garhwal Nappes, and the term 'autochthonous' seems to be justified.

2. Krol Nappe.

The maximum thickness of the succession in the Krol Nappe is of the order of 20,000 feet (6,100 meters). This succession is a normal one, for the disposition of numerous exposures of current bedding in the calc grit of the Tal limestone, and in the Tal and Nagthat quartzites, shows that these particular stages are not inverted, and therefore that the whole succession is in the correct order. This is important because it eliminates the possibility of repetition of certain facies by recumbent folding. Thus, the Tal and Nagthat quartzites cannot be regarded as belonging to a single horizon which has been duplicated by recumbent folding around a core of Upper Krol limestone. This conclusion is also supported by the fact that the sequence of stages above the Upper Krol limestone, on the assumption that this is the core of a recumbent fold, is not the mirror-image reverse of that below the limestone. In particular, there is no equivalent of the Blaini boulder beds in a position between the Lower Tal shales and the Upper Tal quartzites, which would be expected if the Tal and Nagthat quartzites were the same horizon duplicated in a flat overfold. Moreover, there are lithological differences between the Tal and Nagthat quartzites which, though not absolute when regarded singly, are collectively valid enough to differentiate these two stages. This point has been stressed because Middlemiss evidently confused these two quartzites. At the beginning of his survey he considered the Tals to underlie the Massive (Krol)

Lack of inversion.

limestone, but he was later compelled to reverse their position and to place them above the limestone. He appears also in places to have mapped the true Tal quartzites and the Nagthat quartzites that have been overthrust upon the Tals, both as Tal.

It may be accepted therefore that the equence given for the Krol Nappe is uninverted and has not been duplicated by recumbent folding. Nor do I think it possible to assume the duplication by thrusting of uninverted stages one upon another.

The evidence for the existence of this nappe is based upon the following considerations :—

(1) The most convincing evidence is the occurrence of two windows disclosing Nummulitics and Simla slates between Dehra and Rikhikesh. One of these windows occurs on both sides of the Bidhalna Rao (30° 16′ : 78° 14′) and is about six square miles in area. The other window is well seen between Pharat (30° 13′ : 78° 18′) and Banali (30° 11′ : 78° 20′) and covers about seven square miles[1]. They occur along the anticlinal axis which separates the Mussoorie syncline of Nagthat-Blaini-Krol-Tal rocks from the Garhwal syncline lying to the south of and *en echelon* with it. In the centres of the windows occur Simla slates, generally with steep dips. Above the Simla slates, sometimes as isolated cappings, more typically as a border to the windows, are found Nummulitic shales and limestones together with blocks of highly shattered quartzites, the surfaces of which are glazed by friction. Finally, above the Nummulitic and associated rocks occurs the unmetamorphosed facies of the Chandpur beds, belonging to the Krol Nappe. There can be little question here of the Nummulitics occurring as outliers in pockets of a late Cretaceous erosion topography. Such a manner of occurrence would not account for the difference in type of the slates found above and below the Nummulitics. While it is admittedly difficult in some places to distinguish the Simla slates from the Chandpur series (which are possibly of the same age but deposited in two distinct areas), the difference between these two series is on the whole marked enough in this particular region, so that the occurrence of the Nummulitics between the Simla slates and the Chandpurs is significant. The upward succession in these windows, Simla slates—Nummulitics—Chandpurs, is the characteristic

[1] This Banali should not be confused with another village of the same name situated at 30° 18′: 78° 17′30″. The latter village is located on an outlier of the Garhwal Nappes (page 422).

feature, the disposition of the Nummulitics being such as to suggest that they are part of a continuous sequence, a sequence which I conclude to be tectonic. The strong shattering of the quartzites associated with the Nummulitics, their slip-polished surfaces, and their haphazard tectonic isolation as blocks in the shales, with no signs of orderly sedimentation, suggest that these rocks have been subjected to violent stresses. Indeed, below Banali the Nummulitic shales are converted into a 'pseudo-schist', resembling biotite-schist, but in reality a highly sheared shale endowed with abundant reflecting slip surfaces. These effects must have arisen during the Miocene movements, which are known to have been a characteristic feature of Himalayan tectonics, and are indicative of shearing stress rather than simple hydrostatic pressure. On the hypothesis that the Nummulitics rest upon a pre-Tertiary erosion topography, it would, however, be necessary to assume that this topography had undergone little change throughout the Tertiary and Quarternary eras. This would hardly be expected in view both of the extent of the Miocene movements, and of the great erosion which has taken place since then. If Miocene compression had shortened the width of the postulated valleys in which the Nummulitics had been deposited, so as to cause the infolding of the Nummulitics within the Chandpur and Simla slate series, it should have had a devastating effect on the pre-Tertiary north-south ridge separating these valleys. Yet the Chandpur beds of the narrow Diuli (30° 13' : 78° 17') ridge are neither shattered nor highly folded. The shattering occurs in the Nummulitic rocks which dip under the Chandpurs on either side of the ridge. In the view here adopted, the Nummulitics were deposited upon a more or less peneplaned surface of Simla slates, and were later overthrust by the Chandpur series of the Krol Nappe. The valleys in which the inferred windows are now exposed are regarded as the result of recent river erosion. Young river-gravels occur 800 feet above the level of these modern valleys.

(2) Between Solon and Subathu there is a similar disposition to that just described, except that the Chandpur and Nagthat beds of the Krol Nappe are missing. Here the sequence working upwards is:—Simla slates—Subathu (Nummulitic)—Blaini. This area has already been described, being figured on page 436, and discussed on pages 434-437 of *Records, Geological Survey of India*, 67, (1934). Near Solon there are two outcrops of Nummulitics, surrounded by Infra-Krol (Blaini *sensu lato*) slates, which I regard

as windows. The contacts between the Nummulitics and adjacent Blaini rocks are poorly exposed, and it might be maintained that the Nummulitics of these outcrops occur as eroded outliers upon Blaini. Nummulitics are known to lie infolded within Krol limestones at Bagar (30° 45′ : 77° 17′) evidently having overlapped the Tal rocks towards the north-west so as to rest directly upon the Krols, and it might be argued that this overlap continues in the direction of Solon across the Krol limestones on to the Infra-Krol (Blaini). The Krol limestones are, however, very well exposed near Solon, the type locality, so that this overlap could only be very local. Moreover, the same arguments apply to the Solon area as have just been given for the windows south-east of Dehra. Whatever doubts may be raised about these inferred windows, it is difficult, however, to escape the conclusion that the zig-zag disposition of the Simla slates—Nummulitic—Blaini-Krol rocks between Solon and Subathu represents the result of erosion of two tectonic units that had been brought together by thrust movements and were later folded. Here again, in a manner comparable to the windows already described south-east of Dehra, the contrasts between the Simla slates at the base of the Tertiaries and the Blaini slates above them is striking, precluding any explanation by simple infolding of Nummulitics within a single slate series.

(3) On the north-east side of the Krol syncline Nummulitics occur at Sayasu and Dabra, as has been already mentioned (page 417). They overlie Simla slates and appear to underlie the complex group of Chandpurs and Mandhalis. By Koruwa (30° 40′ : 77° 51′), and on the col south-east of Kailana, are found shattered and glazed quartzites exactly similar to those associated with the Nummulitics of the windows between Dehra and Rikhikesh, and around Banas Malla (29° 57′ : 78° 21′), again overlying Simla slates and underlying Mandhali limestones. The thrust which separates the Chandpur-Mandhali rocks from the Simla slates dips southwards, below the Krol syncline. It has been called the Tons thrust and I consider it almost certain that this thrust joins up below the Krol syncline with the north-dipping Krol Thrust on the south side. There is evidence for this supposition along the Huinl river in Tehri Garhwal.

Considering only the first two areas, the minimum displacement of the Krol Thrust and Nappe would be about five miles. Taking into consideration the region on the north side of the Krol syncline

near Kailana, the minimum displacement is likely to be 20 miles (32 km.).

A point which should be emphasised in connection with the Chandpur and Nagthat series of the Krol Nappe is the increase in metamorphism which is observable from the south-west towards the north-east. Along the south-west side of the Mussoorie syncline, for example near Paled (30° 17′ : 78° 11′), the Chandpur series is in the condition of banded green slates and ash beds, while the Nagthat series is made up of soft sandstones and quartzites with a secondary silica cement. Towards the north-east both these series develop schistosity. The Chandpur slates are changed to schistose chlorite-sericite-phyllites, as at Jugargaon (30° 23′ : 78° 24′), while the arenaceous beds of the Nagthat series become schistose chlorite-sericite-quartzites, such as are well seen in the neighbourhood of Kaudia (30° 25′ : 78° 22′). The distance separating these contrasted grades of metamorphism is about 10 miles.

Metamorphism.

3. Garhwal Nappes.

1. Outliers in Tehri Garhwal State.

Ever since I had read Middlemiss's paper on the Physical Geology of West British Garhwal, I had hoped to find a structure in the centres of synclines in Sirmur State and Tehri Garhwal comparable to the one he had described, for I was convinced that the Massive limestone and Tal beds of Middlemiss were equivalent to the Krol limestone and the presumed Tals in Sirmur State. In 1931 a sandy current-bedded limestone was found at the top of the Tal series along the Nigali Dhar of Sirmur State (30° 39′ : 77° 34′) but unfortunately this was the highest horizon exposed[1]. It was not until March 1935 that the expected structure was found at the top of the Tal succession of the Mussoorie syncline on hill 6533 (30° 22′ : 78° 12′). Between Tashla (30° 22′ : 78° 11′), Satengal (30° 21′ : 78° 13′) and Hatwalgaon (30° 20′ : 78° 16′), there was found an outlier of schistose phyllites and subordinate white quartzites overlying a group of limestones, slates and boulder beds, both of which units rest upon and are surrounded by the Tal series. The

[1] *Rec. Geol. Sur. Ind.*, LXVII, Pl. 23, (1934).

area covered by this outlier is about 7 square miles. Equally convincing is another outlier of schistose phyllites lying upon the Tal series around Banali (30° 18′ : 78° 17′ 30″). This outlier is two square miles in area. Both outliers indisputably rest upon Tal beds with centripetal dips varying from 20° to 45°. Adjacent to the Banali outlier is a still smaller outlier, about 200,000 square yards in area, lying as a thin coating upon the Tal quartzites.

It is quite impossible to explain the position of the schistose phyllites upon the Tal series by ring-shaped reversed faults descending through the whole of the 17,000 feet of rocks of the Krol Nappe here present to its basement.

The Satengal outlier is complicated by the presence in its western part of slates, boulder beds, and a limestone identical to the Bansa limestone, which occur between the schistose phyllites and the underlying Tals. Nevertheless, whatever the stratigraphical position of these intervening beds may be, the fact of an overthrust of schistose phyllites upon the Tals is clear and beyond dispute. There is no such complication in the eastern part of the Satengal outlier or at Banali, where the schistose rocks lie directly upon the Tal series, locally with an angular discordance. I showed the Banali outlier to Professor Arnold Heim and Doctor Gansser, both of whom agreed that no doubt could be raised as to its overthrust nature.

The characteristic rock of these outliers is a green schistose chlorite-sericite-phyllite, with segregations of secondary chlorite in streaks. This type can be exactly matched with the rocks at the base of the Krol Nappe around Jugargaon (page 421). The fact that the underlying Tal and Nagthat quartzites are not inverted proves that the schistose phyllites of the outliers above them do not rest in that position as a result of duplication of the Chandpurs which occur at the base of the Krol Nappe by recumbent folding. If recumbent folding were present, either the Tal quartzites or the Nagthat quartzites should be inverted. Further indication of the lack of inversion is suggested by the presence of the limestone, mentioned above, which is similar to the Bansa limestone, and of boulder beds below the schistose phyllites of the Satengal outlier. This relationship is the same as that obtaining in the rocks at the base of the Krol Nappe between Kalsi and Chakrata, where the Bansa limestone and Mandhalis appear to underlie the Chandpur series. That is to say, both in the Krol Nappe and in the Garhwal

Nappe, there is the same succession upwards of these beds. The relationship is, it may be accepted, one of a thrust contact of the metamorphosed type of Chandpurs upon normally lying Tal beds.

In these two outliers of Tehri Garhwal there are two desirable features for demonstrating the complete overthrust of the schistose phyllites upon the Tal series :—

(1) Dips are everywhere centripetally inclined, but are not steep enough to bring the base of the schistose phyllites below the level of river erosion;

(2) the two areas are of a size small enough to be seen almost as a whole by the eye from neighbouring peaks, so that the results of detailed mapping of the thrust boundary may be confirmed and integrated at a single glance.

2. OUTLIERS IN BRITISH GARHWAL.

In coming to the area mapped by Middlemiss in British Garhwal, these two features are absent. Dips are on the whole steeper, and the area is so large that it cannot be taken in by inspection from any one vantage point. I have re-mapped that part of Middlemiss's area which lies in sheet 53 J/S.W., and have traversed along the Nayar river from Byansghat to Bhanghat, Dwarikhal, Lansdowne (29° 51′ : 78° 41′) and Dogadda. The correlations given in table 2 are definitely proved by the results of detailed mapping. The only difference between the Garhwal area and that of Tehri Garhwal is that Nummulitics are present above the Tal series in Garhwal, while they are almost absent from Tehri Garhwal except for very narrow outcrops along the Ganges river. The outcrop of Nummulitics in Garhwal is discontinuous, but is slightly more extensive than shown by Middlemiss.

Overlying the Nummulitics in sheet 53 J/S.W. occur two separate nappes which are disposed in synclines that are separated for some distance by the anticlinal axis running from just east of Lachmanjhula in a south-east direction past Jogyana along the Huill river; Section 2. In the western, Amri, syncline (Amri: 30° 04′ : 78° 22′) the rocks are characteristically green schistose phyllites with subordinate white schistose quartzites, the assemblage recalling at once that of the Satengal and Banali outliers. In the eastern, Bijni, syncline (Bijni: 30° 04′ : 78° 25′) the dominant rocks are purple, green, and white quartzites exactly resembling the Nagthat series,

with underlying and subordinate banded green slates similar to those of the less metamorphosed type of Chandpurs on the south-west side of the Krol Nappe. In the anticline separating these two nappes there crops out a complicated assemblage of Tal and Nummulitic rocks, obviously highly disturbed and interfolded, as may be well seen at Bagurgaon (29° 58′ : 78° 29′).

Between Kothar (29° 58′ : 78° 34′) and Lansdowne there is another and larger syncline of schistose phyllites and white schistose quartzites, similar to those of the Amri, Banali and Satengal synclinal outliers. Intruded into these rocks occurs the gneissic granite of Lansdowne.

It must be admitted at once that there are many difficulties in understanding the Garhwal area. Firstly, I have been able to come to no satisfactory conclusion about the true position of the boulder slate (volcanic breccia of Middlemiss). In the north end of the Garhwal syncline this boulder slate unquestionably joins up with the Blaini, but I am uncertain if the boulder slate so often found lying above the Tal beds of Garhwal is the same as the Blaini. thrust upon the Tals, or if it is an altogether different horizon. Secondly, as seen above, the outcrop of Middlemiss's Inner Schistose series is not made up of a single tectonic unit. These difficulties can only be cleared up by detailed mapping, but, in spite of them, I am confident that the Inner Schistose series of Middlemiss does truly overlie the Nummulitic, Tal and Krol rocks as a thrust outlier. In no other way is it possible to explain the ring-shaped boundary between the older rocks and the Nummulitics around Amri and Palyalgaon (30° 06′ : 78° 24′). Just north of Amri, Middlemiss mapped two faults separating the older rocks from the Nummulitics. The N.W.-S.E. fault is shown as terminating westwards against the N.-S. fault, which is made to pass northwards towards Patna, *without displacing the Nummulitic—Tal boundary*. On the postulate of Middlemiss, this fault should have caused the Outer Formations to be thrown down below their own basement. Its throw would be enormous, and yet it fails to displace the Nummulitic—Tal boundary at all. A re-examination of this area has shown that the schistose phyllites overlie the Nummulitics round an arc of 180° and that the boundary between them is continuous and not made up of the intersection of two or more faults. The reason is clear. The faulted junction between the schistose phyllites of Amri and the Nummulitics does not cut through the Nummulitics

and underlying formations, because it is a thrust plane which lies at an horizon altogether above them; Plate 35 and Plate 37, fig. 2.

Moreover, in the Garhwal area the rock types of the Inner Schistose series are dissimilar to those underlying the Krol series along the Nayar river, both in lithology and in strike. Underlying the Krols from Byansghat to Banghat (29° 57′ : 78° 42′) occur Simla slates with strikes varying from E.-W. to N.N.E.-S.S.W. The Krol—Tal rocks, and the overlying schistose rocks from Dwarikhal to Lansdowne, have a uniform N.W.-S.E. strike. The Simla slates also differ in lithology and degree of metamorphism from the rocks of the schistose series overlying the Krol and Tal series. On the interpretation of Middlemiss, the Simla slates and the Inner Schistose series should be the same, since the reverse faulting which he postulated would have brought up the same foundation rocks upon the Tals as underlie the Tal and Krol series.

It is difficult to picture the mechanics of the reversed faulting suggested by Middlemiss, since it is necessary to assume either that his Outer series have been thrust inwards and downwards towards a centre or that his Inner series has expanded outwards on all sides from a centre over the Outer series. Cone fractures are common features in certain volcanic areas such as the western islands of Scotland, but so far as I know the displacement along these fractures is inconsiderable and is largely a consequence of infilling with magma. The whole difficulty is removed if we accept that the present basin-like disposition is a secondary feature subsequently impressed upon an extensive thrust of the Garhwal units over the Krol unit.

In connection with the question of reversed faulting, I think that Mallet had a truer grasp of the solid geometry required by geological relationships similar to those of Garhwal. When mapping north Bengal and southern Sikkim he realised that the position of the Darjeeling gneiss above the Daling series could not be explained by 'mere local inversion along the lines of contact'[1]. So for as I have seen these rocks in eastern Nepal and Sikkim, the Darjeeling gneiss, though truly above the Daling series, does not appear to be separated from it by a thrust plane[2]. The point it is wished to emphasise here is that both in Garhwal and in eastern Nepal and Sikkim the observed relationship is one involving

[1] Mallet, F. R., *Mem. Geol. Surv. Ind.*, XI, p. 42, (1874).
[2] Auden, J. B., *Rec. Geol. Surv. Ind.*, LXIX, p. 161, (1935).

complete superposition and not local reversed faulting, even though the explanation offered for the manner of this superposition is different in the two cases.

The argument for an extensive thrust plane over the Nummulitic, Tal and Krol rocks of Garhwal may now be summarised.

(1) The Nummulitic, Tal and Krol rocks of Garhwal completely surround the Inner Schistose series (as shown by Middlemiss) and dip below them centripetally. This is well seen around Amri and Palyalgaon in sheet 53 J/S. W.

(2) At Satengal and Banali in Tehri Garhwal State, schistose phyllites lie as indisputable thrust outliers upon the Tal series.

(3) At least two synclines occur within the Inner Schistose series of Garhwal (those of Amri and Lansdowne) in which the schistose rocks are identical in every respect to those found in the indisputable overthrust outliers of Satengal and Banali. In the Lansdowne outlier there is an additional element in the presence of the gneissic granite, which was intruded before the thrust movements had taken place.

(4) Middlemiss argued on the grounds of metamorphism that the schistose series are older than the Nummulitics upon which they lie. Apart from the question of metamorphism, there is no known post-Nummulitic sequence to correspond to the schistose series. From both points of view the schistose series must lie with an abnormal contact upon the Nummulitics and Tal series.

(5) The Inner Schistose series is composed of two main units :—

(*a*) schistose phyllites, slates, schistose quartzites and quartzites, resembling the more metamorphosed facies of the Chandpur series of the Krol Nappe :

(*b*) banded grey-green slates and mainly purple quartzites, resembling the less metamorphosed facies of the Chandpur and Nagthat series of the Krol Nappe.

Neither of these two units resembles, in strike or closely in lithology, the Simla slates which occur at the base of the Outer series along the Nayar river. The more schistose rocks of the Inner series also differ from the Simla slates in metamorphic grade. These facts appear to negative the explanation given by Middlemiss of reversed faulting having brought up the basement of the Outer Formations so as to lie upon them. If reversed faulting had taken place, the basement rocks (Simla slates along the Nayar river) and

the Inner Schistose series should be identical. In the solution suggested in this paper it is believed that the facts are best explained by two thrusts: the Garhwal Thrusts introducing rocks similar to those which in parts of sheet 53 J/S.W. lie at the base of the Krol Nappe, so as to rest above the Krol Nappe; and the Krol Thrust dividing off the Krol Nappe from the Simla slate foundation. This thrust is believed to be transgressive, both towards the south-east in Garhwal, and towards the north-west in Sirmur and Baghat States, with the result that it cuts out successive members from the base of the Krol Nappe.

I would suggest that the arguments given above are sufficient to establish the existence of a great system of thrusts upon the Nagthat-Blaini-Krol-Tal-Nummulitic succession in Tehri Garhwal and British Garhwal. These thrust-nappes exist now as three outliers:—

(1) Satengal outlier, covering about 7 square miles;
(2) Banali outlier, covering 2 square miles;
(3) Garhwal outlier, covering approximately 240 square miles.

The Bijni Nappe is possibly relatively local in origin, but the main nappe of the Garhwal system, which includes the Satengal and Banali outliers, and the Amri and Lansdowne synclines in the Garhwal outlier, has certainly travelled a great distance.

3. FURTHER OUTLIERS OF THE GARHWAL NAPPES.

Besides working in the Lansdowne area of British Garhwal, Middlemiss also mapped a syncline of schists and quartzites intruded by gneissic granite at Dudatoli (30° 03′ : 79° 12′)[1]. He pointed out (page 40) the exact similarity between the gneissic granites of Dudatoli and Lansdowne, and also (page 136) the fact that the only synclines of importance along a line from the Plains to the Main Himalayan Range are connected with the gneissose and schistose series. I would go further in believing that the schistose rocks into which the Dudatoli granite is intruded are the same as those of Lansdowne, Amri, Banali and Satengal, which have already been described. Similarly, the gneissic granite of Ranikhet and Dwarahat is intruded into phyllites of the same type.

There is no evidence in the regions in which I have mapped or traversed for the equivalent of the Jutogh series of Simla described

[1] *Rec. Geol. Surv. Ind.*, **XX**, pp. 40, 136, (1887).

by Pilgrim and West. The granites of Lansdowne, Dudatoli, Dwarahat and Ranikhet appear in all cases to be intruded into phyllites of one type, corresponding to the more metamorphosed facies of the Chandpurs. These rocks may possibly be equivalent to the Chail series of West. The local increase in metamorphism to garnet-chlorite-phyllite, garnet-chlorite-schist, fine-grained biotite-schist, chiastolite schist, which is attributable to contact effects in proximity to the intruded granites, appears to take place in the Chandpur series of schistose phyllites and not in a higher and altogether distinct series such as the Jutoghs of Simla. This fact I can state with certainty to be true of the Lansdowne area where it is definite that there is no additional series above the Chandpurs of the Inner Schistose group. My briefer examination of the Dwarahat-Dudatoli area suggests the same conclusion, one which seems inevitable indeed from the observations of Middlemiss, mentioned in the passage which I have quoted in an earlier paper[2]. In this passage he points out the gradation in a single series from schist to ordinary slate. Mr. West, in a recent discussion of this problem, accepted that the Jutogh Thrust may not be of widespread significance towards the south-east[3].

In all these cases, the schistose rocks, with or without intruded granite, appear to overlie in synclinal form less metamorphosed limestones and quartzites. Consequently, besides the three outliers of the Garhwal Nappes which I have discussed in detail above, I would suggest that the Dudatoli-Dwarahat-Ranikhet-Almora region also represents a syncline or group of synclines which may be outliers of the Garhwal Nappes. In the map (Plate 36) only one generalised syncline has been shown, since no detailed mapping has been done in this area, except by Middlemiss around Dudatoli.

4. AGE OF THE KROL AND GARHWAL THRUSTS.

The maximum age of the Krol Thrust is established by the presence below it of Nummulitic and Dagshai rocks. This thrust cannot, therefore, be older than Burdigalian.

Below the Garhwal Thrusts occur Nummulitics and possible Dagshai rocks. These thrusts are therefore certainly younger than

[1] *Rec. Geol. Surv. Ind.*, XX, p. 137, (1887).
[2] *Op. cit.*, LXVII, p. 412, (1934).
[3] *Current Science*, 111, p. , (1935).

the Eocene, and are possibly, as in the case of the Krol Thrust, not older than Miocene in age. This is in agreement with the recent discovery of Nummulitic and Dagshai rocks by Mr. West in the Shali area, below the Chail Thrust[1].

Since no Siwalik rocks are found in the windows, or below the outliers, it might be assumed that the thrust movements took place after the Burdigalian but before the Siwaliks had time to be deposited there, an assumption which would make the movement about Helvetian in age. If, however, the Siwaliks never extended so far to the north-east, this argument fails, since it is possible to imagine the thrusting to have occurred a considerable time after the Nummulitics and Dagshais had been laid down and while the Siwaliks were being deposited elsewhere.

That some of the movement along the Krol Thrust is more recent than Helvetian is proved by the frequent juxtaposition of pre-Tertiaries upon the Nahans between the Jumna river and north Bengal. Further, in places even the Upper Siwalik conglomerates are involved in overthrust by the pre-Tertiaries. Ten miles north-west of Dehra the boulders of these conglomerates are so shattered that it is impossible to obtain a hand specimen of them. Similar overthrusting occurs at Bilaspur on the Sutlej river (31° 20′ : 76° 45′)[2]. These movements must be of Lower Pleistocene or even of later age. Yet it is difficult to believe that the major horizontal movements of the Krol and Garhwal Nappes over a distance of several miles took place as late as this. By Lower Pleistocene times, the rising Himalayan chain must have been dissected to such an extent into blocks by deeply eroding streams that the upper nappes had already been worn away into outliers. The formation of these upper nappes can only have taken place before erosion had proceeded to such an extent that the outcrops of the nappes along an alignment in the direction of movement had been divided off into separate outliers, unable to translate the stresses as a unit. Both the Krol and Garhwal Nappes have been strongly folded, possibly as a result of the resistance offered by the floor upon which the movement was effected. There has since been erosion of these thrusts with the resulting formation of the windows and zig-zag outcrops, and it may be accepted that the major part of the movement along these thrusts took place before river dissection had

[1] *Rec. Geol. Surv. Ind.*, LXXI, p. 72, (1937).
[2] *Op. cit.*, LXVII, p. 444, (1934).

reached its present pronounced stage. It may, therefore, be assumed that there has been more than one period of movement, the stronger movements perhaps during the Helvetian, and the later movements during the Siwalik and post-Siwalik.

IV. SNOWY RANGES.

I have visited the higher Himalaya of this region twice; in 1932, when a traverse was made up the Alaknanda valley to Badrinath, Mana and the Arwa valley; and in 1935, when the Bhagirathi valley was ascended up to some of its tributary valleys in the neighbourhood of Harsil, Gangotri and Gaumukh. A brief lithological description of the rocks encountered along the Alaknanda valley has already appeared[1]. It is intended here to mention only a few points concerned with the snowy ranges of the higher Himalaya.

Two main zones.

The snowy ranges between the Bhagirathi and Alaknanda valleys may be divided into two zones by a fairly well defined line. The southern zone, forming the Main Himalayan Range as seen from Landour and Lansdowne, consists predominantly of paragneisses and schists, dipping towards the north-east, and presenting a scarp face towards the Plains of India. The northern zone is of granite, out of which the peaks in the Gangotri and Arwa basins are carved. The boundary between these two zones is shown on the map (Plate 37). I disagree with the mapping of Griesbach, who has drawn in the neighbourhood of Harsil and Dharali what appears to me to be an artificial boundary between Haimanta slates and a combined group of granite and metamorphics[2].

Metamorphics of the Main Himalayan Range.

The rocks of the Main Himalayan Range consist of a varied assemblage of schistose phyllites, schists, and granulites intruded by gneissic granite and pegmatite. They rest upon little metamorphosed shales, phyllites, limestones and quartzites, from which they are separated by a thrust plane. This thrust is well seen at Sini (30° 46′ : 78° 36′) and occurs near mile 158 on the pilgrim track from Hardwar to Badrinath. The rocks immediately above the thrust

[1] *Rec. Geol. Surv. Ind.*, LXIX, p. 133, (1935).
[2] *Mem. Geol. Surv. Ind.*, XXIII, (1891).

appear similar to those of the metamorphosed Chandpur series found in some places at the base of the Krol Nappe and more generally in the main Garhwal Nappe.

The main suite of metamorphosed sediments must belong to a different unit. The rocks of this suite were originally shales, shaly sandstones, sandstones, calcareous shales and limestones. In their present metamorphic condition they form a series that is characteristically granulitic, consisting of quartz-biotite-granulites, often with garnet and felspars, quartzites, hornblende-granulites, diopside-calciphyres, marbles, biotite-garnet-schists and kyanite-schists. The calcareous rocks are best developed between Badrinath and Mana, but occur to some extent up the Rudagaira valley (30° 55′ : 78° 54′). It is possible that this suite is equivalent to the Jutogh series of Simla.

Granite zone.

The granites to the north of the Main Himalayan Range probably occur continuously from Dharali (31° 02′ : 78° 47′) eastwards to the Saraswati valley and Kamet peak. Several types of granite are present, including muscovite-tourmaline-granite, biotite-muscovite-granite and adamellite. Porphyritic types are common at Bhaironghati, Jangla and up the Nela (Lamkaga) valley.

Some of these granites are sheared and crushed. The presence of patches of granular blue quartz is suggestive of crushing, a fact which struck my colleague Dr. J. A. Dunn on being shown specimens. Shearing is well seen at a height of 10,300 feet up the Nela valley (about three miles from Harsil), where there is a contact between the granite and overlying metamorphics. The garnet of the metamorphics has broken down retrogressively to chlorite, while the granite has been sheared and mylonitised through a width of 150 feet at right angles to the plane of contact, with the development of marked schistosity and the destruction of the phenocrysts.

It would appear from these facts that some at least of these granites are not post-tectonic in the sense of the post-tectonic granites which cut across the *decken* in the Alps. These strained granites may have been intruded either during the major thrust movements, or at an altogether earlier period. It was considered above that the Lansdowne granite was intruded before the formation of the Garhwal Thrust and that it was pre-Miocene.

V. POSSIBLE NORTHWARD EXTENSION OF THE GARHWAL NAPPES.

It has been stated that the main Garhwal Nappe occurs as synclinal outliers resting upon less metamorphosed rocks. Reasons have been brought forward for regarding the schistose rocks and granite of Dudatoli as belonging to the same overthrust unit as those of the Satengal, Banāli, Amri and Lansdowne outliers. The nearest schistose rocks to the north-east from Dudatoli occur at the base of the Main Himalayan Range, where they too appear to lie with a thrust contact upon less altered limestones, quartzites and slates. It would seem possible, therefore, that the main Garhwal Nappe joins up with the rocks at the base of the Main Himalayan Range and that the minimum distance of translation of this tectonic unit may be about 50 miles (80 km.). It appears that the granites were intruded principally into the Garhwal and overlying units and were thrust with them for miles towards the south-west, over rocks which are free from granitic intrusions, but are in places considerably injected with basic magma.

Finally, comparison may be made with the eastern Himalaya. In eastern Nepal and north Bengal there are two main dislocations :--

(1) the thrust causing the Gondwana rocks to lie upon the Siwaliks :

(2) the thrust separating the Daling series from the underlying Gondwanas.

These two thrusts may be analogous respectively to the Krol Thrust and one of the Garhwal Thrusts. Near Udaipur Garhi (26° 57′ : 86° 32′) there are bleaching carbonaceous slates and a dark crystalline limestone which resemble the Blaini and Krol series of the western Himalaya, and which, like them, rest upon Siwalik rocks.[1] Further, it may be remarked that the schistose phyllites of the main Garhwal Nappe appear to be identical to the Daling series of Nepal and Sikkim. In both areas, these schistose rocks are thrust upon Gondwanas or the equivalent of Gondwanas.

VI. EXPLANATION OF PLATES.

PLATE 35.—Map No. 53 J/S. W., reduced to the scale of 1 inch = 4 miles, showing the disposition of the main tectonic units in the neighbourhood of Dehra and Rikhikesh.

[1] *Rec. Geol. Surv. Ind.*, LXIX, p. 143, (1935).

PLATE 36.—Tectonic Sketch Map of the Garhwal Himalaya, including a portion of 1 : million map No. 53. This map is based on the surveys and traverses of C. S. Middlemiss, C. L. Griesbach, and J. B. Auden. Auden alone is responsible for the tectonic interpretation of the geological results. The limits of the inferred Garhwal Nappe between Dudatoli and Ranikhet are conjectural.

PLATE 37, FIG. 1.—Section across Siwalik Range and Lower Himalaya in 1″=2 miles map No. 53 J/S.W.

FIG. 2.—Section across the composite Garhwal Syncline showing Amri and Bijni Nappes and the unconformity below the upper Tal Calc. grit. (Scale 1″=1 mile.)

FIG. 3.—Tectonic section across the Garhwal Himalaya. A preliminary attempt. (Scale 1″=8 miles.)

MISCELLANEOUS NOTES.

An inclusion of coaly shale in Deccan Trap at Indore, Central India.

Discovery of inclusion.

In July, 1934, the Director of the Institute of Plant Industry sent a sample of 'coal' discovered at a depth of 19 feet from the surface as an inclusion in 'black trap rock' at Indore (22° 43′ : 75° 51′), Central India, during blasting operations in the course of digging a well.

Analyses.

Dr. M. S. Krishnan, who was Curator of the Geological Museum at that time, reported the specimen as 'shaly coal, dull black in colour and showing fine bright streaks of material (presumably of the nature of vitrain)'. It was analysed in this laboratory with the following results, an analysis by Mr. Y. Wad, Chemist to the Institute of Plant Industry, being given for purposes of comparison :—

	Per cent.	Per cent.
Moisture	2·80	..
Volatile matter	20·23	16·595
Fixed carbon	18·92	..
Ash	58·05	58·03
	100·00	
Specific gravity	1·88	2·04
Caking properties	Does not cake	..
Colour of ash	Pink-buff	..
Analyst	Mahadeo Ram	Y. Wad.

The specimen is thus a coaly shale as it contains more than 50 per cent. ash.[1] The powdered mass is registered as N. 857 in the collections of this Department.

Further details of mode of occurrence.

Further correspondence elicited the information that the size of the coaly shale as found was approximately 12 inches × 15 inches × 9 inches. As the well in which the inclusion was found was full of water, it was not possible to send specimens of the rock in which it was embedded until March, 1935, when specimens of trap from above and below the coaly shale were received from Indore.

[1] Fermor, L. L., *Rec. Geol. Surv. Ind.*, LX, p. 345, (1928).

These were collected in the well at depths of 18 feet (47/867, 23888), 21 feet (47/868, 23889), and 23 feet (47/869, 23890) respectively, the first being above the site of the inclusion, and the two latter below it.

The specimens and sections were examined by Sir Lewis Fermor who stated :—'The specimens of both the overlying trap are of porphyritic basalt containing not only abundant phenocrysts of plagioclase, but also altered phenocrysts of olivine, now completely altered to what is probably delessite, with iddingsite in one case. They might be parts of the same flow, the highest specimens showing vesicular tendencies.'

Examination of specimens and sections of trap.

As a result of doubts as to the authenticity of the occurrence, advantage was taken of the visits of Mr. W. D. West to Indore in connection with the Indian Science Congress, and he was requested kindly to examine the well in question. Mr. West stated :—

Additional sections of trap.

'When I visited Indore in October, 1935, the water-level in the well was too high for me to see anything. In January, 1936, however, the water-level was about 25 feet below ground-level. Thanks to Mr. F. K. Jackson, in whose compound the well is, I was able to descend into the well by sitting on a *charpoy* which was let down with ropes. This gave me a good view of the sides of the well all round.

It is quite clear that there is now no trace of coaly shale anywhere in the sides of the well. The information at Indore suggested that the coaly shale was a large "lump" situated towards one side of the well, and not a seam. It occurred 19 feet down. My own observations showed that the sides of the well are entirely trap, and it is clear that the whole of the coaly shale must have been removed when the well was sunk.

Examination of the sides of the well suggested that there might have been a flow junction at 16½ feet down. At this level, there was rather a sharp line all round the well, below which the trap was very "platy" for six or eight inches, while above and below it was more massive. I could see no abundant vesicles near this point.

Cursory examination of the microscope slides (24496-24499) of the rock above and below the possible junction showed that there are slight differences in the rocks, but I did not have time before

leaving for camp to examine the slides very thoroughly. There was nothing to suggest it was a dyke.

There is no doubt whatever regarding the authenticity of the discovery. Unfortunately there is no more of the rock left at Indore.'

Possible origin.

Various theories have been put forward to explain this occurrence, but the one that seems to have most support is that the inclusion is part of an intertrappean shale caught up by a trap flow. Whatever the origin, the occurrence has great interest, and for this reason it is recorded herewith.

A. L. COULSON.

Octahedral Pyrite Crystals from the Kohat District, North-West Frontier Province.

My colleague, Dr. J. A. Dunn, identified as pyrite certain small, slightly distorted, octahedral crystals which I had given me at Kark (formerly Kharak; 33° 7′ : 71° 5′ 30″) in the Kohat district, North-West Frontier Province, when I was inspecting the local oil-shale occurrences in January, 1936. The crystals are found commonly along the Tarkha Algad near Kark in a ?Laki gypseous series overlying the salt marl and are collected by the local small boys. The largest crystals have axes of 7-8 mm., but most crystals have axes of about 5-6 mm.

After the thin göthite covering had been removed by sandpaper from its faces, Mr. P. C. Roy kindly analysed one of the crystals of pyrite for me in the Laboratory of the Geological Survey of India with the following results:—

	Per cent.
Fe	47·09
S	52·40
	99·49

Dr. Dunn's polished section of a crystal showed no traces of magnetite but thin veins of göthite which were irregular in places and then followed cleavage planes. This göthite would account for the high percentage of iron, theoretical pyrite having 46·6 per cent. of iron and 53·4 per cent. of sulphur. A small amount of water must also be present.

Pyrite, of course, is a common mineral in the gypseous series referred to above, and its presence has been recorded often by Wynne and Pascoe amongst others. No reference seems to have been made, however, to crystal forms other than the cube and pyritohedron, though I have a recollection of reading of 'black diamonds', really pyrite crystals of octahedral shape, occurring in a series of age similar to the gypseous series at Kark.

Though Ford[1] says the octahedral form of pyrite is 'also common', almost perfect octahedra of that mineral are rare as there is usually a development of pyritohedral faces with the octahedral. Octahedra certainly occur in Pennsylvania,[2] accompanied by rarer forms with curved faces. Dr. Dunn has noted octahedral faces on pyrite crystals in Bawdwin ores from Burma and Mr. B. C. Gupta has shown me octahedal faces on pyrites in association with quartz and calcite from Kerakibari (25° 45′ : 74° 12′) in the Todgarh tahsil of Ajmer-Merwara.[3] However it would appear that the occurrence of these small octahedra of pyrite near Kark is worthy of record.

A. L. COULSON.

Quarterly Statistics of Production of Coal, Gold and Petroleum in India : July to September, 1936.

Coal.

—	July.	August.	September.	Quarterly total for each Province.
	Tons.	Tons.	Tons.	Tons.
Assam	18,218	17,783	15,994	51,995
Baluchistan	163	345	369	877
Bengal	465,455	524,006	602,413	1,591,874
Bihar	856,095	893,028	1,030,288	2,779,411
Orissa	3,003	1,692	2,475	7,170
Central Provinces	127,109	106,413	97,619	331,141
Punjab	4,306	4,418	10,615	19,339
TOTAL	1,474,349	1,547,685	1,759,773	4,781,807

[1] 'A Text-Book of Mineralogy', after Dana, p. 433, (1932).
[2] Penfield, *Amer. Journ. Sci.*, XXXVII, p. 209, (1889).
[3] *Mem. Geol. Surv. Ind.*, LXV, Pt. 2, p. 169, (1934).

Gold.

—	July	August.	September.	Quarterly total for each Company.
	Ozs	Ozs.	Ozs.	Ozs.
The Mysore Gold Mining Co., Ltd.	8,161	8,162	7,900	24,223
The Champion Reef Gold Mines of India, Ltd	5,885	5,884	5,694	17,463
The Ooregam Gold Mining Company of India, Ltd.	4,349	4,338	4,379	13,066
The Nundydroog Mines, Ltd. .	9,635	9,637	9,619	28,891
TOTAL .	28,030	28,021	27,592	83,643

Petroleum.

—	Crude Petroleum	Total gasolene from natural gas.
	Gallons. •	Gallons.
Assam	16,353,632	*Nil*
Burma	67,489,517	2,222,493
Punjab	996,720	114,606
TOTAL .	84,839,869	2,337,099

* These figures represent the total amounts of gasolene derived from natural gas at the well-head. Of these amounts, a portion is sold locally as 'petrol' and the remainder is mixed with the crude petroleum and sent to the refineries The figures given in the two columns, therefore, together represent the total 'raw products' obtained. These remarks apply to the similar totals quoted in previous *Records*.

A. M. HERON.

through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2.—**Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes : No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east with speckled sandstone in west of Salt-range in Punjab.**

Part 3.—**Retirement of Mr. Medlicott, J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' Meteorite.**

Part 4 (out of print).—**Points in Himalayan geology. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chattisgarh coal-fields. (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Miscroscopic Petrology.**

VOL. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III Birds'-nest of Elephant Island, Mergui Archipelago. Exploration of Jessalmer, with a view to discovery of coal. Facetted pebble from boulder bed ('speckled sandstone') of Mount Chel in Salt range, Punjab. Nodular stones obtained off Colombo.

Part 2.—Award of Wollaston Gold Medal, Geological Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mohowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formations of Simla region of Lower Himalayas.

Part 4.—Indian fossil vertebrates. Geology of North-West Himalayas Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

VOL. XXII, 1889.

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite Generic position of so-called Plesiosauraus Indicus. Flexible sandstone or Itacolumite its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period." Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3.—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-field, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Til mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rajmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provisional Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire. Part 1.

VOL. XXIII, 1890.

Part 1.—Annual report for 1889. Lakadong coal-fields, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicynodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas. Garhwál and Kumaon, Section IV. Bivalves of Olive-group, Salt-range Mud-banks of Travancore coasts.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mine of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3.—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal-fields of Lairungan, Maosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provisional Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

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Observations of the Moon's Surface.—Using a small telescope or field glass, observe the moon when it is only a few days old. Notice that the whole of the disc can be dimly seen. The edge of the bright part of the disc facing the sun is

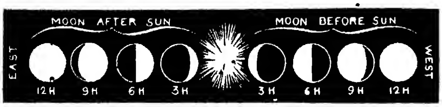

FIG. 7.—Relative times of Rising and Setting of Sun and Moon at different ages of the Moon.

sharply defined, but the line—called the *terminator*—separating the illuminated portion of the disc from the dark portion is irregular in outline, owing to the fact that the moon's surface receiving the sunlight is rugged. If the surface were perfectly smooth, the terminator would be an unbroken arc of an ellipse.

Notice the large dark patches which give the appearance of the "man in the moon" when seen without optical aid; these are still known as "seas," although no water occurs in them. Look at the more or less circular cavities well visible on the surface when the moon is about a week old; these are "lunar craters," and their appearance is much the same as that of large volcanic craters viewed from above. When the moon is a little more than Half Full, look near the terminator in the northern hemisphere (if you use an astronomical telescope, this will be the lower hemisphere in the field of view), and a long range of mountains—the lunar Apennines—will be seen.

Notice the dark shadows on the sides of the large objects observable on the moon; they are directed towards the terminator, and are shadows thrown by the sun. The sharpness of the shadows shows that the moon has no appreciable atmosphere.

EXERCISES.

(1) State what is meant by the "phases of the moon," and explain the cause of them. Draw a diagram showing the relative positions of the sun, moon, and earth at New Moon and Full Moon.

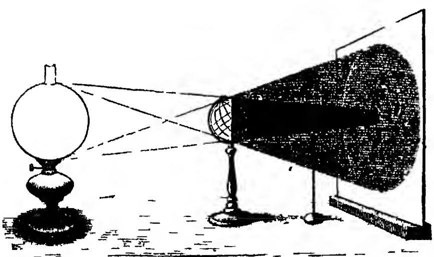

FIG. 8.—Experiment to illustrate the cause of an Eclipse of the Moon.

(2) A novelist describes a ploughman as returning home from work by the light of a *rising* crescent moon. Explain why this is improbable. Draw a diagram—looking from the north—to show the positions of sun, earth, and crescent moon the ploughman actually sees.

(3) Explain the reference to the direction of the horns of the moon in the following lines:—

> O Lady Moon, your horns point towards the east;
> Shine, be increased;
> O Lady Moon, your horns point towards the west;
> Wane, be at rest.

(4) At about what time does the moon rise at the end of the First Quarter and at Full Moon?

(5) Does the moon rise every day of the month? If so, why is it not visible every day?

(6) In a certain work of fiction an eclipse of the sun is described as having occurred the day after Full Moon. What have you to say to this statement?

(7) The battle of Crecy was fought on Aug. 26, A.D. 1346, about a week after New Moon. A

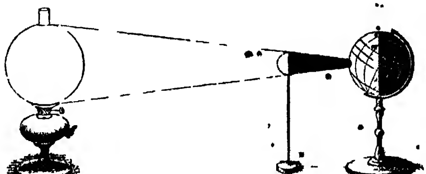

FIG. 9.—Experiment to illustrate the cause of an Eclipse of the Sun.

"fearful eclipse" is reported by some historians to have occurred on the morning of the battle. Show the impossibility of this being a real eclipse either of the sun or moon.

(8) The next total eclipse of the sun will occur on May 17, 1901. On what day in May will there be a New Moon, and about what date will the succeeding Full Moon occur?

(9) Vespucius, observing in the torrid zone and a clear atmosphere, is said to have seen the moon to the east and west of the sun on the same day. Comment upon this statement.

(10) In what direction would you look for Full Moon shortly after sunset?

(11) Artists sometimes depict a star near the concave side of a crescent moon. Explain why this is incorrect.

(12) Comment upon the lines:

> The moon's an arrant thief,
> And her pale fire she snatches from the sun.
>
> *Timon of Athens*, iv., iii.

when the sun is south of the celestial equator the Full Moons are north of it. The sun is south of the equator in the winter months, hence at this time of year the moon being north of it from the First to the Last Quarter (see Fig. 6) is longer above the horizon than in summer; for a large part of its diurnal path is presented to us.

Eclipses of the Moon.—Find from a calendar the dates of three eclipses of the moon, past or future. Find also the dates

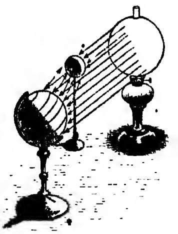

Fig. 5.—Experiment to illustrate Earth Shine.

of the three full moons in the same month. Notice that the dates are the same, thus showing that eclipses of the moon happen at Full Moon. This is true whether the eclipse is total or partial.

Explanation of Eclipses of the Moon.—Place a globe, representing the earth, near a lighted lamp representing the Sun. Notice that a shadow of the globe is thrown by the lamp and can be caught upon a screen. Fix a small ball upon a stand and bring it gradually into the shadow until the centres of the lamp, globe and ball are in a straight line, and the ball is completely immersed in the shadow. This illustrates how an eclipse of the moon is caused by the moon passing into the shadow of the earth. Notice that the ball is in the position for Full Moon when the eclipse occurs. By raising or lowering the ball so as to be only partially in the shadow, the conditions for a partial eclipse of the moon can be illustrated (Fig. 8).

If the plane in which the moon revolves round the earth were coincident with that in which the earth travels round the sun, there would be an eclipse at each Full Moon. But the moon's orbit is inclined to the plane of the ecliptic, and it therefore happens that usually at Full Moon the earth's satellite is above or below the shadow cast by the earth, and no eclipse occurs. At other times the moon partially passes through the umbra, and we have what is known as a *partial eclipse*. It is only when the centres of the sun, earth, and moon are nearly in the same line at the time of Full Moon that a total eclipse of the moon can occur.

Eclipses of the Sun.—Find from a calendar the dates of three eclipses of the sun, past or future. Find also the dates of the three new moons. Notice that the dates are the same, thus showing that eclipses of the sun happen at the time of New Moon. Observe that three kinds of solar eclipses are specified, viz., (1) total eclipse, (2) partial eclipse, (3) annular eclipse. Each of these kinds may be visible or invisible in England.

Explanation of Eclipses of the Sun.—Place a lighted lamp and a globe a short distance apart, and a small ball between them. Let the ball be at such a distance that its shadow only appears as a small spot on the globe. From any point within the spot the lamp could not be seen. The conditions of an eclipse of the sun are therefore illustrated by this arrangement. Notice that the ball is in the position for New Moon (Fig. 9).

Arrange the lamp, ball and globe so that the shadow of the ball does not quite reach the surface of the globe. From a point just under the apex of the cone of shadow, the ball would not completely obscure the light, and a ring or annulus of luminosity would be seen. This illustrates the conditions of an annular eclipse.

In its movement around the earth the moon is sometimes nearer the earth than at others. *Total* solar eclipses, when the sun is quite obscured by the moon, occur when the moon is near its nearest point to the earth, and also close to the ecliptic at the same time. If the moon is near its most remote point, and near the ecliptic at the same time, the shadow cast by the moon falls short of the earth, and consequently the appearance to an observer in the line of the shadow is different. The moon cuts off all the light of the sun except a ring of light surrounding the circle of darkness, and we have what is called an *annular eclipse*. Sometimes the moon does not pass in a direct line between the sun and the earth at New Moon, but is slightly above or below the ecliptic. Under these conditions the sun is only partially covered; so a partial eclipse occurs.

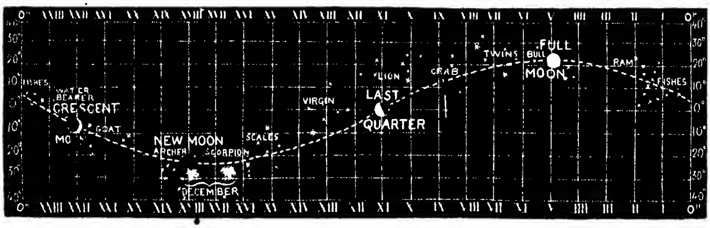

Fig. 6.—Moon's path among the Stars in December

the monthly revolution of the moon around the earth. An observer imagined upon the globe would see the ball projected upon different objects during the revolution of the ball in its orbit. In a similar way the moon is seen projected upon different parts of the celestial sphere on account of its movement around the earth. Unlike the eastward motion of the sun, which is only an *apparent* motion due to the real movement of the earth, the eastward motion of the moon is a *real* motion due to the actual revolution of the earth's satellite.

It will be noticed that the path of the moon among the stars, determined as described, is almost

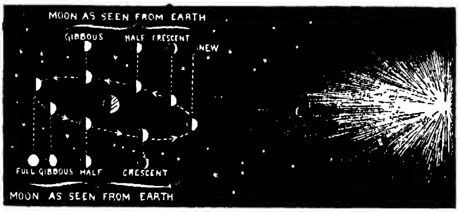

FIG. 3.—Explanation of Phases of the Moon.

the same as the apparent annual path of the sun. The time occupied in making the complete circuit of the heavens in Fig. 6 is from noon on December 1st to a little after noon on December 28th, that is, a little more than 27 days. This (or more exactly, 27¼ days) is the length of a *sidereal month*, and it is determined, as here explained, by observing the interval between two successive appearances of the moon on the same celestial meridian.

Relative Positions of Sun and Moon.—Notice the relative positions of the sun and moon two or three days after the time of New Moon given in a calendar. Make a rough measure of the angular distance between the two bodies. Repeat the observation at the same hour as many nights as possible, and determine from the measures the daily increase of angular distance: it will be found to be about 13°.

Explanation of Relative Times of Rising and Setting of Sun and Moon.—Place the lamp, ball, and globe in the position to represent the cause of New Moon. Rotate the globe slowly on its axis. Notice that the sun (lamp) and moon (ball) would appear on the meridian of any place that is due south at the same time. Move the ball for a short distance in the direction indicated, and again rotate the globe; the sun now rises, souths, and sets a little before the moon. Move the ball to the first Half Moon position, and rotate the globe; there is now a difference of one quarter of a rotation, that is, six hours between the times of rising, southing, and setting of the sun and moon. Place the ball in the Full Moon position; the moon now rises, souths, and sets twelve hours after the sun, that is, at midnight. From this point to the New Moon position the difference between the times of rising, southing, and setting of the sun and moon decreases. At the beginning of the Last Quarter the moon rises, souths, and sets one quarter of a rotation, or six hours before the sun, and this gets less and less until the sun and moon are again upon the same celestial meridian, and there rise, south, and set together (Fig. 7).

When the moon rises only three or four hours after the sun, a few days after New Moon, it cannot be seen to rise because of the overpowering brightness of sunlight. But towards sunset this bright glare is diminished, and the crescent moon is seen above the sun in the western sky. This is what people call the New Moon, though really the New Moon occurred two or three days before. If the earth had no atmosphere, the crescent moon would be seen immediately it appeared above the eastern horizon, and would be visible a little to the east of the sun throughout the day. After the commencement of the last quarter, there is another crescent moon which rises shortly before the sun in the early morning hours, and is overpowered by atmospheric glare when the sun appears above the horizon. From these facts it will be understood that a rising crescent moon could never be seen in the evening, nor a setting crescent moon in the morning.

Knowing the position of the sun upon the celestial sphere at any time, and also the position of the moon, it is easy to determine the relative times of rising, southing, and setting. For instance, in the month of December the sun occupies points on the celestial sphere between the hours XVI. and XVIII. of Right Ascension. The path of the moon during this month is shown in Fig. 6, and also the position of the sun on December 1 and December 21 (Winter Solstice). The Full Moon is seen to be twelve hours distant from the sun, and the New Moon is seen to be a little north of the position the sun occupied on December 22. The relative positions of the sun and moon can be shown graphically in this way upon any date, when the Right Ascensions and Declinations of the two bodies are known, and the diagram thus constructed makes it possible to determine by a glance the relative times of rising, southing, and setting of the two bodies.

FIG. 4.—Earth Shine on the Moon.

As the moon when full is at the opposite point of the celestial sphere from that occupied by the sun, it follows that when the sun is north of the celestial equator the Full Moons are south, and

Demonstration of Phases of the Moon and Related Phenomena.—Place a lighted lamp upon a table, and a globe at a short distance from it; these represent respectively the sun and earth. Obtain a small white ball about one-quarter the diameter of the globe—to represent the moon. Carry the ball around the globe as indicated in Fig. 2, and notice that, though a hemisphere of the ball is always illuminated, the amount of illuminated surface visible from the globe depends upon the

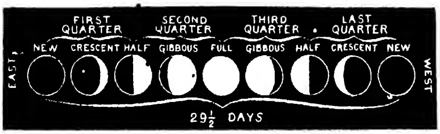

FIG. 1.—Phases of the Moon and length of a Lunation.

relative positions of the lamp, globe, and ball. Show in this way the relative positions of the three bodies, illustrating (1) New Moon, (2) Half Moon, (3) Full Moon, (4) Half Moon again.

Notice that when the ball is between the globe and lamp only the dark side is turned towards the globe. This represents the condition for the astronomical New Moon. Move the ball a little in the direction indicated, and a crescent of light can be seen from the globe, just as the crescent moon becomes visible a few days after New Moon.

The moon is shown in several positions in its path in Fig. 3. In every position sunlight is illuminating a complete hemisphere, but it will be seen that the form and extent of the visible illumination depends upon the relative positions of the earth and moon. At New Moon the illuminated hemisphere is turned away from the earth, so nothing is seen of our satellite. As the moon travels in the direction indicated, first a crescent of light is seen, then the Half Moon, then the gibbous phase, and afterwards Full Moon, at which time the whole of the illuminated hemisphere is seen, the moon being directly opposite the sun. From Full Moon to New Moon, again, it will be noticed that the changes occur in the same order.

As the moon derives its light from the sun, the illuminated part of its surface must always face the sun. This explains why the crescent moon seen in the evening always has its horns pointed away from the sun, that is, towards the east, while in the crescent moon which rises shortly before the sun, the horns are pointed towards the west.

Earth Shine and its Cause.—Look for the crescent moon as early as possible after New Moon. The dark body of the moon can usually be seen embraced by the crescent of light on one side (Fig. 4). The appearance can always be seen with a small telescope.

Place a lamp, ball, and globe in the relative positions for illustrating the production of a crescent moon a few days after New Moon (Fig. 5). Notice that the globe as well as the ball is illuminated, and that the reflection of the light from the globe causes the hemisphere of the ball facing the globe to be faintly visible. The moon receives *Earth Shine*, or sunlight reflected from the earth, in the same way a few days before and after New Moon, and thus produces the phenomenon observed.

The phenomenon is known as the "old moon in the young moon's arms." It will be noticed that the bright crescent moon appears to be part of a larger body than the dark portion. This is, of course, not actually the case, the effect being due to what is known as *irradiation*, on account of which a bright object appears larger than a dark one to the eye, and its image tends to spread out on a photographic plate.

Eastward Motion of the Moon.—Notice the position of the moon on any night. Repeat the observation several nights at the same hour. Observe that every night the moon is further east at the same hour than it was the night before. Notice that on account of this the position of the moon with reference to the stars continually changes.

Determination of Moon's Path among the Stars.—From *Whitaker's Almanack*, or a similar publication, find a date when the moon's Right Ascension at noon is not far from zero. Using squared paper as in Fig. 6, make a mark at the proper Right Ascension and the corresponding Declination of the moon on the date found. Locate similar points upon the squared paper to show the Right Ascension and Declination of the moon every day at noon as given in the Almanac, until the XXIVth hour of Right Ascension is reached. Connect the points thus determined; the line obtained shows the path of the moon on the celestial sphere in the month selected.

Interval between Successive Southings of the Moon.—Fix a simple theodolite or pointer so that a sight can be taken due south. Observe the times at which the moon appears due south on several nights in succession. The time of transit will

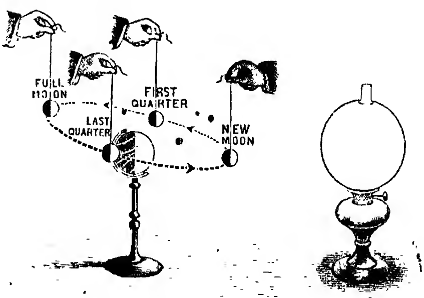

FIG. 2.—Experiment to illustrate the cause of Phases of the Moon.

be found to be about fifty minutes later every night. The times of rising and setting are correspondingly belated. Test this statement by means of the times of rising or setting of the moon given in a calendar.

Explanation of Eastward Motion of Moon.—Place the lamp, ball, and globe upon the table as in Fig. 2. Imagine objects and marks upon the walls, floor, and ceiling of the room to represent stars. Carry the ball around the globe to represent

education is largely a matter of conjecture. But there are signs which enable one to form some idea of how primary instruction is likely, should the present conditions continue, to be modified in the near future. Elementary education will gradually pass into the hands of women.

If the reader will visit a pupil teachers' school in a large town, like, to name any two examples, Birmingham or Cardiff, the disparity in the number of boys and girls being trained will be impressed upon him in a way which no words can manage. And not only is there this inequality in the numbers, but there is a similar preponderance of ability on the side of the girls. These potential schoolmistresses are picked girls, the best children of the elementary schools from which they come. The boys are good fellows enough, no doubt, but they are in no sense the best boys of their years at school. The smartest boys have found their way into factory and workshop. To put the matter shortly, the girls are generally the intellectual superiors of the boys.

In the course of time, then, it is clear, there will not be elementary schoolmasters enough to supply the number of boys' schools in existence. The first result will be a Headmaster with a staff of women assistants. But this can last only as long as it is possible to obtain able men of the same stamp as those who administer our elementary schools at the present time. The intellectual superiority of the women, becoming year by year greater, will eventually become so pronounced that it will be impossible to ask the highly-endowed and excellently-trained mistress to occupy a position subordinate to a man who is so manifestly her inferior in all mental activities. Then the heads of the schools will have to be chosen from among the women. There will, doubtless, for some time continue to be men assistants, but they will become fewer and fewer until eventually the only subjects entrusted to men teachers will be manual training, drill, and physical exercises. In any event, unless the present tendency is stopped in some way or another, the elementary schoolmaster will become as extinct as the dodo.

This substitution of women for men teachers does not take place so rapidly as the difference in numbers of the boy and girl pupil-teachers would lead one to suppose, because the ranks of the mistresses are being continually thinned by an ever-present counter-attraction to the pedagogic passion. A considerable percentage of the women become married every year, and the duties of married life, in the case of the wives, interfere so much with the demands of a school that, as a rule, to be married is for a woman to resign her position as a teacher.

The usurpation of the woman teacher is going on in America in just the same way. Consider the following numbers from "The Report of the Commissioner of Education" for the United States for the year 1897-98. The numbers apply entirely to the "common schools," which include the public schools of elementary grade—the first eight years of a course of study—and the secondary grade—ninth to twelfth years of the course of study:—

	1879-80.	1889-90	1897-98
Male teachers	122,795	125,535	131,750
Female teachers	163,798	238,397	277,443
Per cent. of male teachers	42·8	34·5	32·2

If these conclusions are correct, and if this usurpation of women is considered undesirable, it is manifestly of the highest importance that immediate steps should be taken to improve the attractiveness of the schoolmasters' prospects. It must be made as worth while for a bright, intellectual boy to become a teacher as to go into a factory, a warehouse, or a shop. He must be able to earn as much; his future must appear just as hopeful; and in some manner the public estimate in which he is held must be improved. It is all very well for School Board candidates to talk of the nobility of the teacher's work, to refer to the high esteem in which the public hold him, and the honoured old age to which he can look forward. But to have a real effect in counteracting the tendencies to which attention has been drawn, these assertions of election times must be translated into facts of which there can be "no possible, probable shadow of doubt, no possible doubt whatever."

OBSERVATIONAL ASTRONOMY.

A SERIES OF NOTES UPON THE POSITIONS AND APPARENT MOTIONS OF CELESTIAL BODIES.

By R. A. GREGORY, F.R.A.S.

Professor of Astronomy, Queen's College, London.

V.—THE MOON AND ECLIPSES.

(Concluding Article.)

Length of a Lunation.—Find the time of New Moon from a calendar. Observe the moon two or three nights later; and when you think it is Half Moon reckon the number of days that have elapsed since New Moon. In a similar way, find the number of days from Half Moon to Full Moon, from Half Moon to Last Quarter, and from Last Quarter to New Moon.

The following dates, for instance, have been obtained in this way.

			Dates of Quarters. D.	H.	M.		Lengths of Quarters. D.	H.	M.
	New Moon,	April,	13	4	23	A.M.			
1st Quarter,	Half Moon,	April,	20	10	47	P.M.	7	18	24
2nd Quarter,	Full Moon,	April,	27	1	47	P.M.	6	15	0
3rd Quarter,	Half Moon,	May,	4	3	25	P.M.	7	1	38
Last Quarter,	New Moon,	May,	12	7	46	P.M.	8	4	21
Total Length of Lunation							29	15	23

The Average Length is 29½ Days (Fig. 1).

The shape of the moon should be drawn from week to week in connection with these observations.

Occasionally one is led by the class into unexpected places. After finding that when acid acts on metal, and hydrogen is evolved, there is no evidence to show either that the hydrogen comes from the metal or from the acid, the large majority of a class adopted the hypothesis that the hydrogen comes partly from the metal and partly from the acid. They have at present to test the validity of that hypothesis, and I shall be interested to see how they do it.

I have dealt above with a few selected subjects. I hope to deal with others on another occasion.

In conclusion, I would repeat my conviction that rational and heuristic teaching untrammelled is interesting and invigorating alike to teacher and taught—as part of a compromise it is a failure.

THE SUPPLY OF PUPIL TEACHERS.

THE character of English elementary education depends more upon the teachers in the public elementary schools than upon any other determining factor. Any considerations which influence the training, the supply, or the status of elementary teachers will have an immediate and profound effect upon primary instruction. Fortunately, this vital importance of the teacher has been very fully recognised in recent years—a fact which has resulted in great improvements in the care taken to prepare him for his work. Prominent among such steps in advance are the changes effected in the training of pupil teachers.

Schools expressly intended for the instruction of young apprentices have been provided in every town of any importance. It is now understood, moreover, that if he is to learn satisfactorily, the young teacher must not first have his energies sapped by a day's work of trying to keep a large class of little children in order, and of endeavouring to teach them something as well. A town pupil-teacher spends but half his day imparting knowledge; the other moiety is devoted to his own intellectual growth. Not only so: whereas a few years ago he was entirely dependent upon his headmaster for all the instruction he could get, which, in an understaffed school, was precious little, the pupil teacher of to-day has at his disposal a staff of specialists, often graduates, who have made a study of his particular requirements. A pupil teacher's lot, in other words, should be a fairly happy one.

It might reasonably be supposed that concurrently with these improved conditions a keener and keener competition for the position of pupil teacher would have been noticed between the brightest boys of the elementary school. If, with all the disadvantages under which the apprentice laboured a few years ago, there was little difficulty in obtaining as many boys as pupil teachers as the schools required, surely now, with improved conditions, the only difficulty is an increased trouble of selection in view of the larger number of applicants. This is a natural train of reasoning. But the exact opposite appears to be true. In towns, at all events, side by side with the apparent attractiveness of a pupil teacher's life, an increased difficulty in getting boy apprentices has grown up. In many large manufacturing, and in some distributing centres, scarcely a boy pupil-teacher can be obtained locally. Even those boys who are secured are the second best. The pick of the elementary schools are drafted into works and warehouses.

The reasons for this are not far to seek. They are chiefly questions of *£ s d*. In large towns a lad leaving an elementary school at the age of, say, fourteen or fifteen can obtain a larger weekly wage if he goes into a factory or warehouse than if he is apprenticed as a pupil teacher. The working-class parent has very little faith. One of his favourite proverbs is "A bird in the hand is worth two in the bush." With no power of looking forward, a parent of this kind is totally incapable of comparing a successful elementary schoolmaster and a successful artizan at, say, the age of thirty. It is this want of imagination rather than selfishness which leads the parent to prefer the factory to the school. The immediate gain to themselves they understand; the future prospects of their son do not so strongly appeal to them.

But though this is the chief reason for the scarcity of boy pupil-teachers, there are other minor causes tending to bring about the same result. One of these is the inadequate provision of training colleges. Only about a third of the candidates who yearly present themselves at the Queen's Scholarship Examination can—so limited is the accommodation—expect to enter a training college. The trained teacher monopolises the good posts in the public elementary schools, and the chances of a place in a training college may well seem remote to the parents of a boy who is to be provided with some work in life. This difficulty of supply has, up to the present, only been experienced in the case of the boys. There is no dearth of girl pupil-teachers. On the contrary, the supply is said to be, in some districts at least, in excess of the demand. The result is that the managers of schools are able to pick and choose in the case of the girls, while in the case of the boys they have to take what they can get and be thankful. The methods sometimes adopted in the selection of the girls form an interesting study, which cannot, however, be entered upon here.

It is worth while to point out, to prevent misapprehension, that it has not been lost sight of by the writer that the scarcity of male pupil-teachers is, at present, confined to the towns. In rural districts the difficulty has not been experienced to anything like the same extent. But these facts interfere in a trifling degree only with the results arrived at. This scarcity of youngsters from elementary schools who want to take up teaching as a profession has only held true for a comparatively small number of years, and consequently the effect it is likely to have on elementary

with passing events I might, if occasion offered, refer to "Blue-Books," say what they were and show a specimen. They are printed. But before printing? And before there was writing? Anything besides tradition? Gradually we work out our evidences and classify them under three heads—tradition, contemporary documents, human products. We illustrate these copiously and comment on the inaccuracies of tradition and the mistakes of the scribe. This introduction works very well, and for some time after rather incredible stories are good-humouredly scoffed at as "only tradition." Our investigations as to evidence lead us back naturally to pre-historic periods, to "early-stone men," "cave men" and "later-stone men." Pictures are used freely.

Coming to early historic times, authorities are given, the earliest extant MSS. mentioned, and cases noted where doubtful evidence may be confirmed by "remains." The life of the people, their dress, armour, houses, even their government, have been found emphatically interesting to the boys. It is facts which cannot be, or are not, "pictured" which dull their interest. Of course, the very dull boy remains dull, and the boy who belongs to the type of inaccurate-erratics is still inaccurate, but the interest is living and productive. In the course of some later work, and when dealing with another period, I happen to show the class a picture of the doorway of a Saxon church. "But where is the long and short work?" a boy of eleven exclaims, and another suggests, "Perhaps it is only at the corners of the tower."

Thirty or forty years ago the plan was somewhat thus: *Teacher* (*clinging closely to the book*): "What was the fate of the Duke of Clarence?" *Answer* (*supposed to be "History"*): "He was drowned in a butt of Malmsey, of which he was extravagantly fond."

Geography is of course really a science subject. The scale-plan introduction has already found its way into elementary schools, and it is unnecessary for me to enlarge here upon the importance of map "reading." But one serious difficulty confronts us. There are no rational maps. All school maps are constructed on the assumption that geography merely consists in knowing where places are. One admirable atlas has, however, been published, Longman's "New Atlas," but it is a little expensive (a good atlas must be), and the parent wants education as well as other things cheap—at whatever cost. But with the help of Longman's I have succeeded in giving fairly clear ideas of contours, hachures, height colouring, isotherms, rainfall, currents, &c. I have only to compare the maps of England and Africa by the colour scale to elicit an astonished "Oh!" which signifies an impression that no contours or hachures could produce.

It is easy to excite interest in the causes of physical features and their connection with commerce, and a good deal of intelligence is displayed in working out problems. Moreover, the worked-out results are much the best remembered. Where will the agricultural counties be? Why? What industries would you expect at the mouth of the Tyne? Why should the Thames become important? Where would you expect to find remains of the cave men? What kind of ground would you choose for railways? Where, then, would your railways run in hilly country? Compare the courses of the railways and the rivers. Where would you expect to get building stone? To such questions good answers can almost always be got, and a great measure of the commercial information can thus be drawn out of the boys themselves. They at least begin to realise that man's work is "conditioned" by his surroundings, and the facts which they learn, though fewer than those attempted of old, have at least some meaning and persistence.

Science is, of course, *par excellence*, the heuristic subject. If we were to plant some of these pea seeds with the roots pointing up, what would happen? *Answer*: They would not grow. Let us try it, then, and we conclusively establish the property of geotropism. A small boy of ten was asked how he could show a number of people that a pea-seed swelled on soaking. He was rather puzzled, and then said: "Oh, I know; get a ring that the dry pea-seed would just pass through and then soak it. You could show then that it wouldn't go through." This boy had certainly not heard of Gravesande's ring, or of any similar experiment. How could you determine the area of a circle? From their previous acquaintance with other figures the three boys interrogated deduced these answers:—(1) Divide into quadrants. Draw chords. The resulting triangles will be too small. Produce the sides of two opposite triangles, taking the tangent as base. These will be too large. Sum the four triangles, and so get the approximate area. (2) Inscribe and circumscribe a square. Take the mean of the areas. (3) Circumscribe a square, and deduct the triangular corners.

Mere guessing with judgment sometimes produces remarkable results, as when a boy, knowing nothing of the subject, estimated the volume of a sphere as two-thirds that of the circumscribing cylinder. Or when another guessed that on doubling the push on a gas you would halve its volume. But guessing of this sort is only, as a rule, to be used to suggest hypotheses to be tested.

Chemistry works out well on the lines suggested in my article in The School World of October, 1899. Boys are keen to get over each new difficulty. But here a word of caution is needed. The boy can only take one step at a time. So, step by step, he will work out a long train of reasoning. He will think out each step, but to recapitulate the whole train will probably be beyond him. That is no argument against the heuristic method. It is simply a limitation of the immature mind. Each bit of reasoning makes the boy readier at the next step, and, what is most important, the boy learns to *expect* to have to work out things for himself. That is an immense gain. Presently the power to grasp a long argument as a whole will follow.

mention it if there were any other in existence; but the only other collection of ancient portraits obtainable will cost, when completed, £100.

The appetite whetted with a taste of these delicacies, I am much mistaken if the student will not go further. Mr. Ruskin says we value books more the more they cost us; and advises those who cannot buy "Modern Painters" to save up their dinners for a few years. Sixty-three dinners at a shilling would give good value in Baumeister's "Denkmaler der griechischen Altertums," where the history of sculpture and painting, of architecture and the arts, and the results of modern excavations, are arranged in alphabetical form (Oldenbourg, Leipzic). The chief pictures of this fine book are reprinted as "Bilderhefte" for schools (12s.); the execution is poor, the arrangement leaves much to be desired (would these worthy Germans had a little of the French neatness!), but the book is useful to those who have a smattering of German. Pauly's "Realencyclopadie" and Darenberg and Saglio's "Dictionnaire des Antiquités" will also be treasures to those who live to see them completed. Roscher's "Lexicon der Mythologie" (Teubner, Leipzig) is another useful book to one who knows how to sift wheat from chaff; there are tons of chaff in it, and enough wheat to feed an army. He who takes an interest in excavation and exploration would do well to get Miss Sellers' "Schliemann's Excavations" (18s.), or those fascinating volumes in which the explorer tells his own story (they can all be bought for £5), with Dorpfeld's "Troja." Messrs. Macmillan are bringing out a series of capital "Handbooks to Classical Antiquities," which include, besides those mentioned, "Roman Coins" (9s.), "Greek Sculpture" (10s.), and "Greek Constitutional History" (5s.), and will include "Greek Vases" and other subjects of interest not treated hitherto in any brief form. The mythologist will find a library of information in Frazer's "Pausanias" (£6 6s.), and a most careful and judicious statement of facts and theories in Farnell's "Cults of the Greek States" (Clarendon Press). Mr. Roberts's "Greek Epigraphy" (Pitt Press, vol. i., 18s.) supplies not only a history of the letters but a useful collection of dialect inscriptions, which are given more fully in Collitz' "Sammlung der greichische Dialektinschriften" (Vandenhoeck, Gottingen); while Mr. Hicks collects those inscriptions which bear on Greek history, and Mr. Hill other historical *Sources* (Clarendon Press, 10s. 6d.). Lanciani (2 vols., £2 8s.) and Middleton (2 vols., Black) have written on *Rome*, and Wachsmuth on "Die Stadt Athen" (Teubner). For the literary student, much may be learnt from Croiset's "Littérature Grecque" (Teubner), Butcher's "Lectures," Sellar's "Roman Poets of the Republic" (Clarendon Press, 10s.), "Virgil" (9s.), and "Horace" (7s. 6d.), Haigh's "Attic Drama" (Clarendon Press), even from Symonds's "Greek Poets" (2 vols., 7s. 6d. each), despite its bad style. But this is to build castles in the air: I fear my fairy godmother will not rise to the height of this great argument.

SOME IMPRESSIONS OF RATIONAL METHODS.

By HAROLD PICTON, B.Sc. (Lond.)
Headmaster of Clacton College, Clacton-on-Sea.

To teach scientifically will always be more difficult than to teach mechanically. But scientific teaching—not the teaching of science—is imperatively demanded, and we must find out how to give it.—Henry E. Armstrong.

I am convinced that the method of teaching which approaches most nearly to the methods of investigation is incomparably the best. -Edmund Burke.

THE wave of the newer teaching beats at present in vain against the strong sea-wall of tradition which protects our secondary schools from all vital change. New subjects are added to the curriculum, laboratories with complex fittings are thrown open to the parent's astonished gaze, but at heart the schoolmaster still measures attainment by information and information by examination results. It therefore behoves those of us who wish to train the minds of our pupils to action, not mere reception, to unite our efforts and consult each other. For these reasons I am hopeful that a few jottings of some impressions of mine may prove useful to those who wish to work on the same lines.

First let me say that I consider rational teaching a very bad subject for compromise. To try to get the ordinary examination attainments and at the same time throw in a little of the research method is as unsatisfactory as trying to serve God and Mammon. I know this because I have tried it. To succeed on rational lines you must begin with a revolution, not a compromise.

Another general observation is that rational methods are very difficult to apply where a boy has made progress on ordinary lines. By small boys of eight to ten these methods are readily and enthusiastically appreciated. A boy of fifteen who has been taught on the pump-and-bucket system will be stonily amazed when you expect him to think out a subject for himself. A boy of twelve will take to rational methods if he has learned "little" at school. If he has learned "much" he will probably have much lost the power of thinking.

Obviously some subjects can be made more strictly "heuristic" than others. History cannot be drawn out of boys, but it may often be used to exercise reason, and it need never be deprived of meaning. Waiving formal history with the youngest boys to begin with boys of about eleven somewhat thus. What were you doing this morning at a quarter-past eight? What yesterday at such an hour? What last year at such a time? You are not sure. Tell me of some adventure that a friend had some time ago. How do you know? Tell me of something that happened lately to a distant relative. Such questions introduce us to the distinction between evidence handed down by word of mouth (tradition) and contemporary documents. In connection

A TEACHER'S LIBRARY OF CLASSICS.

By W. H. D. ROUSE, M.A.
Assistant-Master in Rugby School.

FIVE pounds sterling will not go far in buying classical books. Even annotated additions are becoming dearer, and eighteen shillings or twenty-four shillings is no uncommon price to pay for one. A dictionary and a lexicon, with dictionaries of mythology and biography, would swallow up more than five pounds at a gulp; and these books are quite indispensable. Books which contain many illustrations are dearer still, and most branches of classical learning have their own monographs or text-books which will mount up to many pounds in each branch Pictures and photographs available for class teaching are numbered by thousands, and there is practically no limit to the amount which the enthusiastic teacher may spend on them. I must assume, then, that my readers have their Liddell and Scott, their Lewis and Short, and their Smiths of various denominations, besides the standard works which they must have used in their own studies; Grote, Arnold and Mommsen, Roby and Goodwin, some ancient atlas, and the texts of the chief classical authors.

If, with these to start with, my fairy godmother should present me with a five-pound note and her blessing, and should inform me that, as I was now grown up, she must leave me and look after her other godchildren, I think I should expend that note upon large pictures which I could use in class, and trust to luck, or to my own brains, or a free library, for the rest; but if there be any who have no free library at command and no accommodating friends, and no luck and too little confidence in their brains, or if such persons should prefer to spend their five pounds on a set of books which might give them a cursory oversight over the fields they intended to conquer, perhaps the following suggestions might be of use to them.

In such a case I should first buy Dr. Gow's "Companion to School Classics" (6s.), which really gives a taste of almost all divisions of antiquities. Dr. Gow puts things in a number of nice little nutshells, kernels very fresh and juicy, which make you desire to go a-nutting for yourself. There is a vast deal of information in this small book, but it is not pemmican like some I could name. The few illustrations would at once make me crave for more, and I should buy Macmillan's "Atlas of Classical Antiquities" (21s.), edited by Mr. Anderson, where there are pictures in plenty and full explanations. Tearing myself away with reluctance from this department, which has already swallowed up one-fifth of my godmother's farewell gift, not to count the blessing, I should turn to the less materialistic portions of ancient life, to the philosophers and the historians. It is more profitable to know what the ancients said themselves than what the moderns say about them; so for half-a-sovereign I should possess myself of Ritter and Preller's "Historia Philosophiae." In this book are collected all the philosophic theories, from Thales to Proculus and Damascius, stated, so far as possible, in the philospher's own words, and arranged chronologically by subject and school. An intelligent man may work out his philosophy from this book alone, and, even if he has his Grotes and his Grants, the compilation is indispensable. He may add to it Mayor's little "History of Ancient Philosophy" (3s. 6d.), if he will, and should his tastes lie in this direction, he may expend later and illuminate Zeller, Lewes and Benn with Kant and Rosmini. For history, law or custom, as well as for epigraphy, it is advisable to have Cauer's "Delectus Inscriptionum Graecarum" (7s.) and Cagnat's "Epigraphie Latine" (12s.); Thompson's "Greek and Latin Palaeography" (Kegan Paul, &c., 3s. 6d.) is a most useful adjunct. Cauer may suggest an excursion into linguistics, and the results of modern research will be found summed up in Giles's "Elements of Comparative Philology" (Macmillan, 10s. 6d.). Mythology now claims our attention, and Miss Harrison's "Mythology and Monuments of Ancient Athens" (Macmillan, 16s.), though not a complete treatise by any means, is well calculated to awaken interest and stimulate further study. There is a good deal in the book also about the ancient city of Athens, which we will supplement by Lanciani's "Ruins and Excavations of Ancient Rome" (Macmillan, 16s.), while Roman myth and legend is judiciously treated in "The Roman Festivals," by W. Warde Fowler (Macmillan, 9s.). Literary criticism remains for the last, and no critical work has been written with finer taste and truer appreciation than Longinus "On the Sublime" (Pitt Press, 9s.).

So far I am well within my godmother's gift. Here is the list:

				£	s.	d.
Cauer's "Delectus"				0	7	0
Cagnat's "Epigraphia"				0	12	0
Ritta and Preller				0	10	0
	£	s.	d.	1	9	0
Gow's "Companion"	0	6	0			
Macmillan's "Atlas"	1	1	0			
Giles's "Philology"	0	10				
Thompson's "Palaeography"	0	13	6			
Harrison's "Mythology"	0	16	0			
Lanciani's "Rome"	0	16	0			
Fowler's "Festivals"	0	9	0			
Longinus	0	9	0			
	4	10	0			
Discount	1	2	6			
				3	7	6
				£4	16	6

There is almost enough to buy Long's "Myth, Ritual and Religion" (7s., cash 4s. 8d.), where we may learn the connexion between ancient faith and modern folk-lore; or dare, I suggest, without egotism, that instead of a bottle of claret to celebrate the founding of the library, one might send to Mr. Dent for a certain "Atlas of Greek Portraits" (two parts, 1s. 6d.)? I would not

MANCHESTER GRAMMAR SCHOOL.

MODERN TIME-TABLE.—MICHAELMAS TERM, 1900.

		vi.	Tr.	v.	R.	4a.	4b.	3a.	3b.	3c.	2a.	2b.	2c.	1a.	F.F.P.
MONDAY	I.	+	+	+	+	+	G	+	+	M a	t h	e m	a t	i c s	+
	II.	Maths.	+	D	+	+	+	D	Writ. or Bk-Kg.	D	+	+	D	+	+
	III.	+	M a t	h e m a	t i c s	D	+	+	D	+	+	+	+	Writ. or Bk-Kg.	D
	IV.	+	D	+	D	+	+	+	+	Writ. or Bk-Kg.	G	+	+	W'shop	+
	V.	+	+	+	+	M a	t h e	m a t	i c s	+	+	W'shop	+	D	Maths.
TUESDAY.	I.	Maths	+	+	+	Chem	istry	+	+	+	D	G	Writ. or Bk-Kg.	+	Writ. or Bk-Kg
	II.	Writ. or Bk-Kp.	+	+	+	Chem	istry	G	D	+	G	D	+	+	+
	III.	+	M a t	h e m a	t i c s	+	+	D	+	Writ. or Bk-Kg.	+	+	+	+	D
	IV.	+	C h e	m i s	t r y	+	D	+	+	M a	t h	e m	a t	i c s	+
	V.	+	+	Chem	istry	M a	t h e	m a t	i c s	+	+	Writg or Bk-K.	W'shop	G	Maths
WEDNESDAY.	I.	Maths.	+	+	G	+	+	+	G	G	+	Writi Book-	ng or K'ping	+	+
	II.	+	+	+	D	D	+	+	+	+	D	D	+	Writ. or Bk-Kg	+
	III.	+	M a t	h e m a	t i c s	+	+	Writ or Bk-Kg.	+	D	+	+	D	+	G
	IV.	Spanish or Chm	+	+	+	+	D	+	Writ. or Bk-Kg	M a	t h	e m	a t	i c s	+
	V.	G	+	D	+	M a	t h e	m a t	i c s	Writ. or Bk-Kg.	W'shop	+	+	G	Maths.
THURSDAY.	I.	Maths.	+	+	+	+	+	Chem	istry	+	Writ. or Bk-Kg.	+	D	+	Writ. or Bk-Kg
	II.	+	G	+	+	+	+	Writ. or Bk Kg.	D	D	D	Writ. or Bk-Kg.	+	+	+
	III.	+	M a t	h e m a	t i c s	Writ or Bk-Kp.	+	+	+	+	+	+	G	+	G
	IV.	+	+	+	+	+	D	+	Writ. or Bk-Kg.	M a	t h	e m	a t	i c s	+
	V.	Spanish or Chm	Chemy	G	+	M a	t h e	m a t	i c s	+	+	+	+	D	Maths.
FRIDAY.	I.	+	+	+	+	+	+	+	+	M a	t h	e m	a t	i c s	+
	II.	Maths.	+	D	D	+	G	Writ. or Bk Kg.	+	+	+	+	D	+	Writ. or Bk-Kg.
	III.	+	M a t	h e m a	t i c s	+	+	+	+	Chemy	Writ. or Bk-Kg.	+	+	+	D
	IV.	+	+	+	+	M a	t h e	m a t	i c s	+	+	D	Wri i Book	ng or K'ping	W'shop
	V.	Spanish or Chm	D	+	+	D	+	D	W'shop	+	+	+	+	D	+

+ Signifies that the class is with the Form or Language-Master (including English and Foreign Modern Languages).
G = Gymnasium. D = Drawing

MANCHESTER GRAMMAR SCHOOL.

CLASSICAL TIME-TABLE.—MICHAELMAS TERM, 1900.

		vi.	Tr.	v.	Rd.	Rβ.	iv.d.	iv β.	iii.d.	iii.β.	ii.d.	ii β.	ii.v.	SPECIAL. M.vi.	Sc.vi.	Sc.v.	M.E.
MONDAY.	I.	+	+	+	Fr	+	+	+	D	D	D	+	G	+	Physics	Chemy	+
	II.	+	M	a t	h e	m a	t i	c s	+	+	+	+	Fr	L a n	g u a	g e s	+
	III.	+	+	+	+	G	Physics	+	+	+	Fr	G	+	+	Mathe	matics	+
	IV.	+	+	+	+	+	+	+	M a	t h	e m	a t	i c s	Chemy	Physics	Che	mistry
	V.	+	Ger	D	D	+	+	D	Fr	Writing	+	+	+	+	Physics	Chemy	Chemy
TUESDAY.	I.	+	M	a t	h e	m a	t i	c s	+	Fr	+	+	+	L a n	g u a	g e s	+
	II.	Ger	+	+	+	+	+	Physics	M a	t h	e m	a t	i c s	L a n	g u a	g e s	D
	III.	+	G	Fr	+	D	+	+	+	Physics	+	Writing	+	+	Mathe	matics	+
	IV.	+	Ger	+	+	+	Fr	+	+	+	Writing	W'p	Writing	+	Physics	D	+
	V.	+	+	+	D	+	G	D	+	+	Fr	+	D	+	Physics	D	+
WEDNESDAY.	I.	+	M	a t	h e	m a	t i	c s	+	+	+	+	Fr	L a n	g u a	g e s	+
	II.	Ger	+	+	+	+	+	Fr	M a	t h	e m	a t	i c s	+	+	G	+
	III.	+	+	D	+	+	D	+	Physics	+	+	Fr	+	+	Mathe	matics	+
	IV.	Maths	+	+	Fr	D	+	+	+	G	W'p	+	D	Chemy	+	+	+
	V.	G	Ger	+	+	+	+	D	D	+	Writing	D	+	+	G	+	+
THURSDAY.	I.	+	M	a t	h e	m a	t i	c s	+	+	+	+	+	L a n	g u a	g e s	+
	II.	+	+	+	+	+	+	Fr	M a	t h	e m	a t	i c s	L a n	g u a	g e s	+
	III.	+	+	+	+	+	+	+	Fr	D	D	D	+	+	Mathe	matics	Chemy
	IV.	+	+	G	D	+	Fr	+	D	+	+	+	W'p	+	+	+	+
	V.	+	+	D	+	Fr	D	+	+	+	+	Writing	+	+	+	+	+
FRIDAY.	I.	+	+	+	+	+	+	+	G	Fr	D	D	Writing	Chemy	+	+	+
	II.	+	M	a t	h e	m a	t i	c s	+	+	+	+	+	Chemy	+	+	+
	III.	+	+	+	+	+	+	+	Fr	D	G	Fr	D	+	Mathe	matics	+
	IV.	+	+	Fr	G	D	D	G	+	+	+	+	+	L a n	g u a	g e s	+
	V.	+	+	+	+	Fr	+	+	M a	t h	e m	a t	i c s	G	Physics	Chemy	G

+ = Class is with the Form or Classical Master (including English as well as Classical Languages). G = Gymnasium. D = Drawing. Fr = French. Ger = German. W'p = Workshop. M.vi. = Mathematical Sixth. Sc.vi. = Science Sixth. Sc.v. = Science Fifth. M.E. = Matriculation Form.

when it is asked to draw a perpendicular on a plane from a given point not in the plane, we are often told to draw a perpendicular from a point in the plane, and draw a parallel to it through the given point.

ALGEBRA.—*Definitions.*—Such terms as *term, factor, power, expression, equation, identity*, are frequently defined wrong. Very few pupils know what a term is. A power is more often than not confused with an index. "A power is the small figure placed at the right-hand top corner of a letter to denote its value" is a definition which suggests a postage stamp. "An equation is where you have to find x; an identity is where you have to prove something" has been given. And there might be worse definitions even than this. "Permutations are arrangements, combinations are selections," is not very explicit. To make a little variety, we have "A permutation is the number of ways, &c.," and sometimes "A combination is the number of ways things can be combined."

Misuse of the Sign of Equality.—This is one of the commonest mistakes of beginners, who will solve a simple equation thus:—

$$\frac{3x-1}{2}=4$$
$$=3x-1=8=3x=9$$
$$=x=3=\textit{Answer}=\textit{Right!}$$

Clumsy Methods of Squaring and of Multiplying Sums by Differences.—When the square of $a+b$, or $a+b+c$, or the product of $3x+4y$ into $3x-4y$ has to be obtained, a large proportion of examinees fail to use the standard formulæ and instead write the one factor under the other, rule a horizontal line, put down the rows of products, rule another horizontal line and add the terms up laboriously, often making a mistake in the work.

Wrong Dimensions.—In multiplying two homogeneous expressions together, say, $a+b+c$ and $a^2+b^2+c^2-bc-ca-ab$, it is common to find such terms as a^2b occurring in the product, when a slight knowledge of "dimensions" on the part of the candidate would show that such terms are obviously wrong and would probably lead to the mistake being corrected.

Want of Symmetry.—In the same example, ignorance of the principle of symmetry leads to such answers being sent up as "$a^3+b^3+c^3-ab^2 \ldots -3abc$."

Neglect of Denominators of Fractions.—Of this the following is a typical example:—

$$\left(\frac{1}{2}x+\frac{1}{3}y-\frac{1}{4}z\right)\times\left(\frac{1}{2}x+\frac{1}{3}y+\frac{1}{4}z\right)$$
$$=(6x+4y-3z)\times(6x+4y+3z),\ \&c.$$

Violation of Laws of Algebra in Working with Surds.—Whenever surds enter into an expression, they seem to lead to repeated violations of the laws of algebra. If it is required to solve the equation

$$\sqrt{(x+3)}-\sqrt{(x-2)}=2\sqrt{(x-1)},$$

we usually have one or other of two different forms of wrong answer, namely $(x+3)-(x-2)=2(x-1)$, &c., or $\sqrt{x}+\sqrt{3}-\sqrt{x}+\sqrt{2}=2\sqrt{x}-1$, whence $2\sqrt{x}=\sqrt{3}+\sqrt{2}+1=\sqrt{6}$, &c.

Verifications instead of Proofs.—If it is asked to prove (*e.g.*) that a^2+b^2 is not less than $2ab$, it is frequent to find candidates proceeding thus:—"Let $a=1$ and $b=2$, &c." If marks are awarded proportional to the portion of the question answered, such answers should receive infinitely small marks (*i.e.*, no marks at all), since an infinite number of cases ought to be discussed before the theorem could be considered proved!

Begging the Question in Verification.—On the other hand, when it is asked to verify that $a(b+c)=ab+ac$ for $a=3$, $b=2$, $c=4$, we have answers standing thus:—

$$3(2+4)=3.2+3.4$$
$$i.e.\quad 3.2+3.4=3.2+3.4$$

in which the truth of the law to be verified is assumed in passing from the first to the second line, on the left-hand side.

Progressions.—Even the most backward pupil may be reasonably expected to know something about progressions. But it is only necessary to set a geometrical progression with a negative ratio, preferably a negative fractional ratio, to "stump" a large proportion of even fairly advanced candidates.

TRIGONOMETRY.—Here again definitions are a fruitful source of error. "The sine of an angle is the perpendicular over the hypotenuse" is common. *What* perpendicular and *what* hypotenuse is left to the imagination of the examiner. We have seen "hypotenuse" spelt in almost every conceivable way *short* of "hippopotamus." Even better prepared candidates fail to give definitions applicable to angles of any magnitude. Of other mistakes the most frequent is that exemplified by "$\tan\theta=1=45°$."

Much has been said against our present examination systems, but it is only by the application of written tests that teachers can ascertain the points which their pupils fail to grasp; and that pupils can be made to acquire an exact understanding of the meaning of fundamental principles and the methods of using these principles accurately in practical applications.

TYPICAL SCHOOL TIME-TABLES.

IN beginning a series of Typical School Time-tables in our last number, we were able to bring before the notice of our readers the scheme of work of a large public school of the boarding-school type. This month, owing to the kindness of Mr. J. E. King, the High Master, we are able to publish the time-table of Manchester Grammar School, than which it would be impossible to find a more effective example of the large public day-school. With the aid of the explanatory notes at the foot of the time-tables of the different sides of the school, there will be no trouble in immediately understanding the way in which the day is divided in the various forms.

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OF

THE GEOLOGICAL SURVEY OF INDIA.

RECORDS

OF

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1937.

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PLATE 2.—FIG. 1.—Side of 298 A, showing the arrow-headed form of the stone.

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FIG. 3.—Side of 298 C, showing numerous crustal depressions.

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FIG. 4.—*Matonidium indicum*, sp. nov. Ribbed axis expanding at the lower end, probably a petiole of this species. Similar fragments are seen in Plate 20, figs. 1 and 6. [G. S. I. type No. 15, 782.]

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FIG. 6.—*Matonidium indicum*, sp. nov. Transverse section of a pinnule. × *ca.* 15. [G. S. I. type No. 15, 784.]

PLATE 22.—FIG. 1.—*Matonidium indicum*, sp. nov. Part of a fertile pinna seen from the upper side. × 2. [G. S. I. type No. 15, 785.]

FIG. 2.—*Matonidium indicum*, sp. nov. Part of a fertile pinna seen from the upper side. × 3. [G. S. I. type No. 15, 786.]

FIG. 3.—*Matonidium indicum*, sp. nov. Several fertile pinnules showing the lower (sporangiferous) surface. × 7. [G. S. I. type No. 15, 787.]

FIG. 4.—*Matonidium indicum*, sp. nov. Part of a fertile pinna seen from the upper side. [G. S. I. type No. 15, 788.]

FIG 5.—*Weichselia reticulata*. Mould of main rachis with parts of secondary rachises attached, showing paired scars of vascular strands of pinnules. [K33/730.]

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FIG. 2.—*Weichselia reticulata*. [K33/731.]

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FIG. 4.—*Weichselia reticulata*. × 3. [K33/731.]

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FIG. 10.—? *Thinnfeldia* sp. Fragment of frond. × 3. [K33/736.]

PLATE 24.—*Matonidium indicum*. sp. nov. Reconstruction of a frond as seen from the abaxial side.

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FIG. 2.—Same specimen, showing trilobed character of the unbroken extremity.

FIG. 3.—Same specimen. Lateral view, showing 'dorso-ventral' ridge and acute middle lobe of the preserved end of the specimen.

PLATE 26.—Geological map of parts of the Shan States and Yunnan. (Scale 1 inch= 32 miles.)

MGIPC—M—VIII-4-1—25-10-37—800.

Fig. 1.

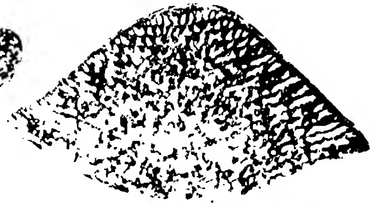


Fig 4

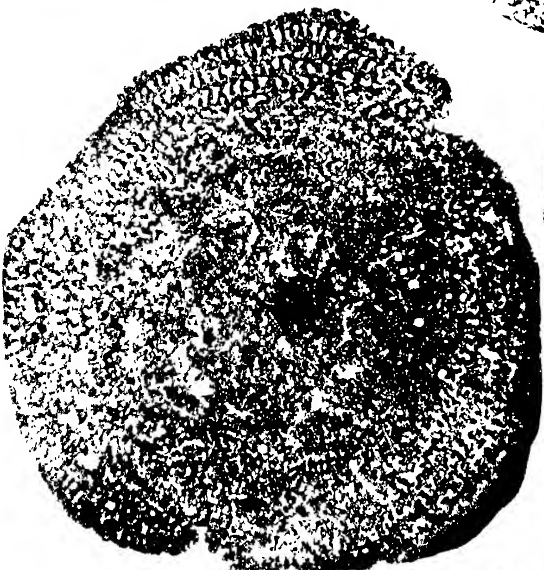


Fig. 2

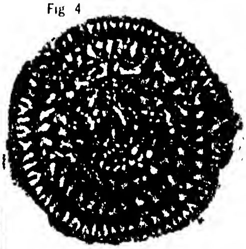


Fig 5

Fig. 6

Fig. 3.

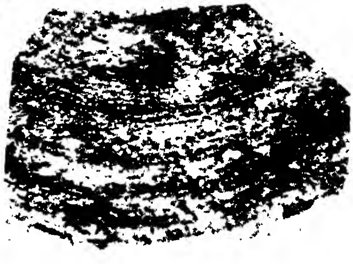
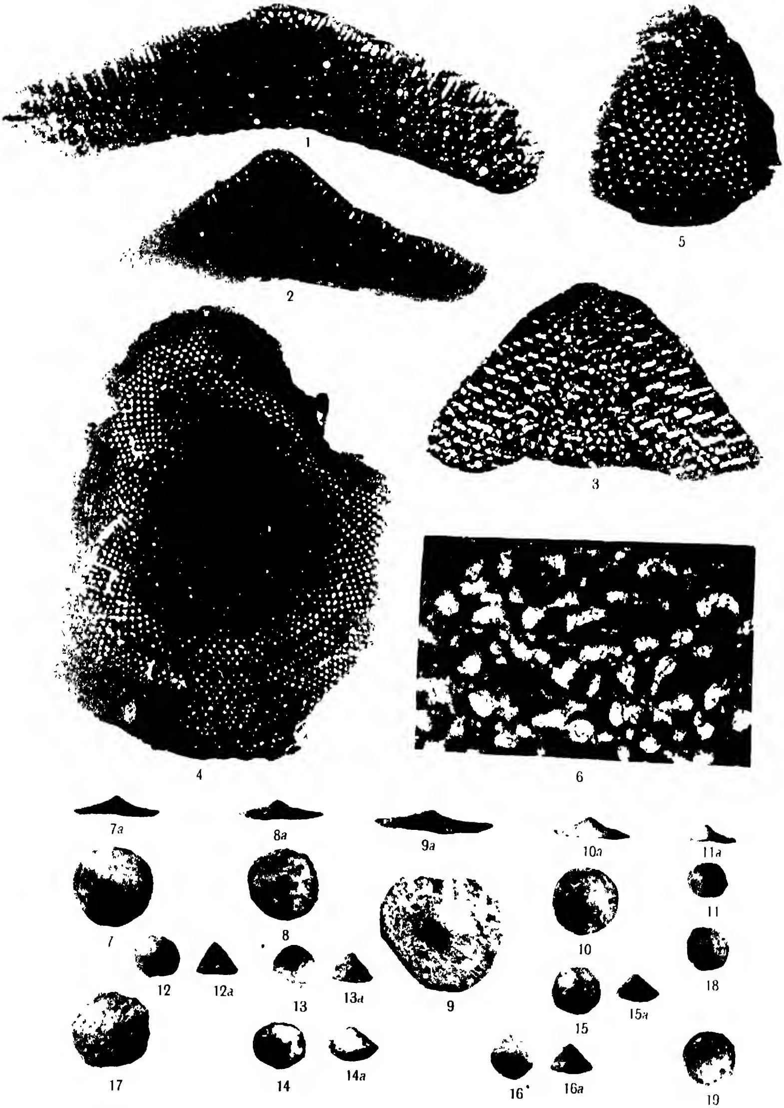


Fig. 7.

M. R. Sahni & S. N. Das Photos

G. S. I., Calcutta

ORBITOLINA BIRMANICA, *sp nov*, FROM UPPER BURMA (× 16)



M. R. Sahni & S. N. Das, Photos. *G. S. I., Calcutta*

ORBITOLINA BIRMANICA, *sp nov*, FROM UPPER BURMA

(Figs 1 5, × 16, fig. 6, × 64, figs. 7--19, × 2)

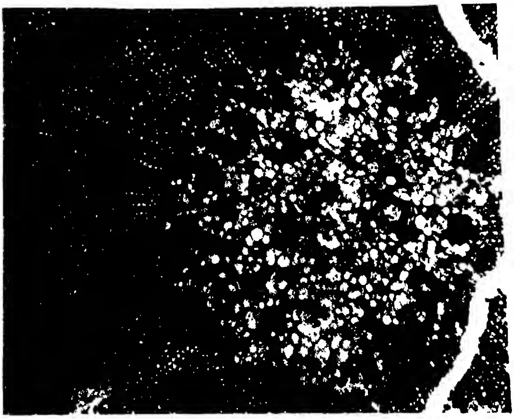


Fig 1 (× 35)

Fig 4 (× ca 235)

Fig 5 (× ca 235)

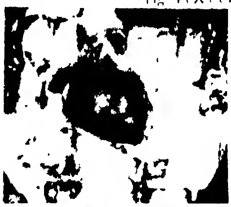


Fig 6 (× ca 118)

Fig 2 (× ca 200)

Fig 3 (× 32)

K. N. Kaul, Photo *G. S. I., Calcutta*

MESEMBRIOXYLON SHANENSE, *sp. nov*

Fig 1 (× 100)

Fig 2 (× 100)

Fig 3 (× 50)

Fig. 4 (× 100)

Fig 5 (× 120)

Fig. 6 (× 150).

Fig 7 (× 100).

Fig 8.

Fig 9 (× 60)

S. R. N. Rao & K. S. Rao, Photos *G. S. I., Calcutta*

FORAMINIFERA FROM INTER-TRAPPEAN BEDS NEAR RAJAHMUNDRY.

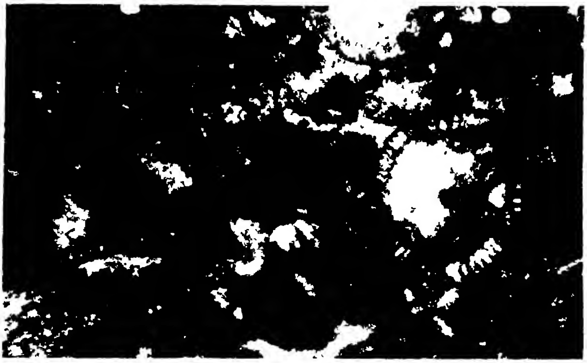
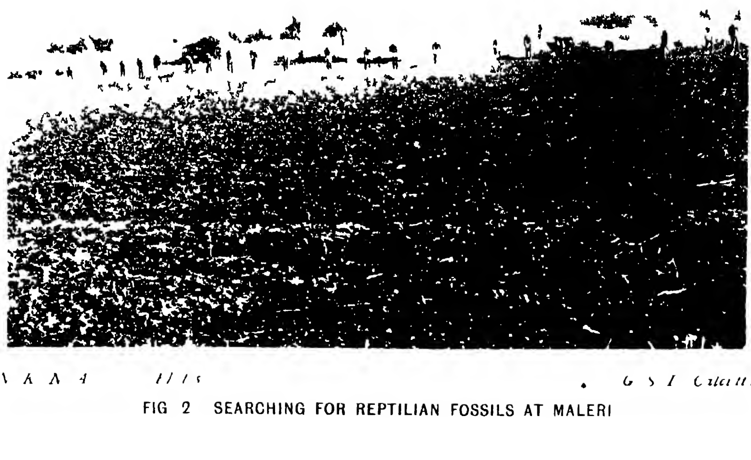


FIG 1. SECTION OF PAUGADI LIMESTONE SHOWING SPHEROIDINELLA *sp.*, GLOBOTRUNCANA, *sp*, AND CALCAREOUS ALGA, ACICULARIA (× 80)

S. K. N. Rao & K. S. Rao, Photos. *G. S. I., Calcutta*

FIG. 2 SECTION OF PAUGADI LIMESTONE SHOWING SPHEROIDINELLA, *sp*, GLOBOTRUNCANA, *sp*, AND CALCAREOUS ALGAE, NEOMERIS AND ACICULARIA. (× 50)

FIG. 1. EXPOSURE OF MALERI BEDS AT RAMPUR NEAR MALERI



G. S. I. Calcutta

FIG. 2. SEARCHING FOR REPTILIAN FOSSILS AT MALERI

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA.

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Part 1 (out of print). –Annual report for 1867. Coal-seams of Tawa valley. Coal in Garrow Hills. Copper in Bundelkhund. Meteorites.

Part 2 (out of print).—Coal-seams of neighbourhood of Chanda. Coal near Nagpur. Geological notes on Surat collectorate. Cephalopodous fauna of South Indian cretaceous deposits. Lead in Raipur district. Coal in Eastern Hemisphere. Meteorites.

Part 3 (out of print).—Gastropodous fauna of South Indian cretaceous deposits. Notes on route from Poona to Nagpur *viá* Ahmednuggur, Jalna, Loonar, Yeotmahal, Mangali and Hingunghat. Agaté-flake in pliocene (?) deposits of Upper Godavary. Boundary of Vindhyan series in Rajputana. Meteorites.

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Part 3 (out of print). - Geology of Kutch, Western India. Geology and physical geography of Nicobar Islands.

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Part 3 (out of print).—Borings for coal in Godavari valley near Dumagudem and Bhadrachalam. Narbada coal-basin. Geology of Central Provinces. Plant-bearing sandstones of Godavari valley.

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Part 3 (out of print).—Maskat and Massandim on east of Arabia. Example of local jointing. Axial group of Western Prome. Geology of Bombay Presidency.

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Part 3 (out of print).—Celt in ossiferous deposits of Narbada valley (Pliocene of Falconer): on age of deposits, and on associated shells. Barakars (coal-measures) in Beddadanole field, Godavari district. Geology of parts of Upper Punjab. Coal in India. Salt-springs of Pegu.

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Part 2 (out of print).—Geological notes on route traversed by Yarkand Embassy from Shah-i-Dula to Yarkand and Kashgar. Jade in Karakash valley, Turkistan. Notes from Eastern Himalaya. Petroleum in Assam. Coal in Garo Hills. Copper in Narbada valley. Potash-salt from East India. Geology of neighbourhood of Mari hill station in Punjab.

Part 3 (out of print).—Geological observations made on a visit to Chadderkul, Thian Shan range. Former extension of glaciers within Kangra district. Building and ornamental stones of India. Materials for iron manufacture in Raniganj coal-field. Manganese-ore in Wardha coal-field.

Part 4 (out of print).—Auriferous rocks of Dhambal hills, Dharwar district. Antiquity of human race in India. Coal recently discovered in the country of Luni Pathans, south-east corner of Afghanistan. Progress of geological investigation in Godavari district, Madras Presidency. Subsidiary materials for artificial fuel.

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Part 3 (out of print).—Shahpur coal-field, with notice of coal explorations in Narbada regions. Coal recently found near Moflong, Khasia Hills.

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Part 4 (out of print).—Gold-fields of Mysore. Borings for coal at Beddadanol, Godavari district, in 1874. Supposed occurrence of coal on Kistna.

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Part 2 (*out of print*).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruption rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

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Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate. "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

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Part 2 (out of print).—Oil near Moghal Kot, in Sheráni country, Suleiman Hills. Mineral Oil from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-spring near Bawgyo, Thibaw State.

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Part 2 (out of print).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan). Gohna Landslip, Garhwal.

Part 3 (out of print).—Cambrian Formation of Eastern Salt-range. Giridih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn., and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.

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Part 2 (out of print).—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.

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Part 2.—Obituary: Ernest (Watson) Vredenburg. Fossil Molluscs from Oil Measures of Dawna Hills, Tenasserim. Armoured Dinosaur from Lameta Beds of Jubbulpore. Fossil forms of Placuna. Phylogeny of some Turbinellidæ. Recent Falls of Aerolites in India. Geology of part of Khasi and Jaintia Hills, Assam.

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Part 3.—Gyrolite and Okenite from Bombay. Freshwater Fish from oil measures of Dawna Hills. Fossil Ampullariid from Poonch, Kashmir. Calcareous Alga belonging to Triploporelleæ (Dasycladaceæ) from Tertiary of India. Froth Flotation of Indian Coals. Submarine Mud Eruptions off Arakan Coast, Burma. Cretaceous Fossils from Afghanistan and Khorasan.

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Part 3.—Mineral Production of India during 1926. Geological Traverse in Yunaslin Valley. Ambala Boring of 1926-27. Indian Unionidæ.

Part 4.—Relationship between Specific Gravity and Ash Contents of Coals of Korea and Bokaro: Coals as Colloid Systems. Contact of Basalt with coal-seam in the Isle of Skye, Scotland: Comparison with Indian examples. Barakar-Ironstone Boundary near Begunia, Raniganj Coal-Field. Raniganj-Panchet Boundary near Asansol, Raniganj Coal-Field. Permo-Carboniferous Marine Fauna from Umaria Coal-field. Geology of Umaria Coal-field, Rewah State, Central India. Composition and Nomenclature of Chlorophæite and Palagonite, and on Chlorophæite Series. Miscellaneous Notes.

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Part 4.—Erratics of the Punjab. Cretaceous Dinosaurs of Trichinopoly District, and Rocks associated with them. Orbitolinæ from Tibet. Joya Mair Dome Fold, near Chakwal, Jhelum District, Punjab. Occurrence of Allophane at Tikak, Assam. Miscellaneous Note: Australian Species of Genus *Gisortia*.

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Part 2.—Methods of Analysis of Coal used at Government Test House, Alipore, Calcutta, with an Editorial Introduction. New fossil localities within Panchet series of Raniganj Coalfield. Species of *Cyllene* from Pegu Beds of Burma. Two new species of *Unio*. Glaciers of Karakoram and Neighbourhood. Miscellaneous Note: Dome near Mari in Attock District.

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Part 3.—Mineral Production of India during 1930. Geology and Lead-ore Deposits of Mawson, Federated Shan States. Weathering of Vindhyan Building Stone. *Maclurites* from Ordovician of Burma. Miscellaneous Notes: Supplementary note on "Revisions of Indian Fossil Plants, Part II Coniferales (*b*. Petrifactions), 1931" and Eruption of Mud Volcano off Arakan Coast.

Part 4.—Reaction Minerals in Garnet-Cordierite-Gneiss from Mogok. Vindhyans of western Rajputana. Granitic Intrusions in Ranchi and Singhbhum Districts. Miscellaneous Notes: *Chonetes* in Krol Limestone; Green Mica from Bhandara District; and Olivine-Basalt and Tuffs in Malani Series at Jodhpur.

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Part 4.—Stratigraphic significance of Fusulinids of Lower Productus Limestone of Salt Range. *Dadoxylon Zalesskyi*, a new Species of Cordaitean trees from Lower Gondwanas of India. Fossil Pentalocular Fruit from Pondicherry. Kalava (Calwa) 'Wall' in Kurnool District. Talc-Serpentine-Chlorite Rocks of Southern Mewar and Dungarpur. Age of certain Himalayan Granites. Tables of Production, Imports, Exports and Consumption of Minerals and Metals in India.

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Part 2.—Geological Reconnaissance in Southern Shan States. Geology of the country between Kalaw and Taunggyi, Southern Shan States.

Part 3.—Mineral Production of India during 1932. Geological Notes on Traverses in Tibet made by Sir Henry Hayden in 1922. Origin of Streaky Gneisses of Nagpur District.

Part 4.—Geology of the Krol Belt. Crush Conglomerates of Dharwar Age from Chota Nagpur and Jubbulpore.

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Part 2.—Cambrian-Trias Sequence of North Western Kashmir (Parts of Muzaffarabad and Baramula Districts). Preliminary account of Earthquake of 15th January, 1934, in Bihar and Nepal. Obituary: Pramatha Nath Bose. Miscellaneous Notes: Barytes in Manbhum District, Bihar; Soda Deposit and Manufacture of Caustic Soda and Crude Soap at Parantij, Ahmedabad District; Potash content of *Reshta*, Sambhar Salt Lake, Rajputana; Alunogen from Cuddapah District; and Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1934.

Part 3.—Mineral Production of India during 1933. Manganese-Lime Series of Garnets. Chemical Composition of Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India; April to June, 1934.

Part 4.—Soils of India. Lateritisation of Khondalite. Snout of Biafo Glacier in Baltistan. Turonian Ammonite (*Mammites Daviesi*) from Ramri Island, Burma. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1934; Tertiary Rocks near Puri; and Cretaceous and Eocene Volcanic Rocks of the Great Himalaya Range in North Kashmir.

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Part 2.—Traverse in Himalaya. Jabalpur Plants from Satpura Gondwana Basin. *Rhizomopsis* Gothan and Sze and *Dictyopteridium* Feistmantel. Sphaerosiderite, containing a New Species of *Dadoxylon* (*D. parbeliense*), from Lower Gondwana Coal Measures of India. Earthquakes recorded by the Pendulum Seismograph at Shillong (Assam) from 1903 to 1931. Preliminary Geological Report on Baluchistan (Quetta) Earthquake of May 31st, 1935. Miscellaneous Notes: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1935 and Gypsum in Upper Vindhyans of Rajputana.

Part 3.—Mineral Production of India during 1934. India's Coal Resources. (Being a note on the reserves available in India of good quality coal including coking coal.) Results of Low-Temperature Carbonisation of some Lower Gondwana Indian Coals. Attrition tests on Stones used as Road-Metal in India. Obituary: James Malcolm Maclaren. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold, and Petroleum in India: April to June, 1935.

Part 4. Buchanan's Laterite of Malabar and Kanara. Solubility of Quartz. Natural Gas at Gogha, Kathiawar. Pitwar Meteoric Shower of the 29th July, 1935. *Fermoria minima*: A Revised Classification of Organic Remains from Vindhyans of India. Ore minerals from Bawdwin, Shan States. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: July to September, 1935.

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Part 2. Perpeti Meteoric Shower of 11th May, 1935. Tirupati and Bahjoi Meteorites. *Ostrea* (*Crassostrea*) *gajensis* from near Baripada, Mayurbhanj State. *Matonidium* and *Weichselia* in India. Cretaceous Cephalopods from Red Beds of Kalaw and Age of Red Beds. Contributions to the Geology of the Province of Yunnan in Western China: 9—Brachiopod Beds of Lan-rum and related formations in Shan States and Indo-China. Geological Age of Namyau, Lan-wan and Napeng Beds and of certain other formations in Indo-China. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: January to March, 1936.

Part 3.—Mineral Production of India during 1935. Marble of the North-West Frontier Province. Miscellaneous Note: Quarterly Statistics of Production of Coal, Gold and Petroleum in India: April to June, 1936.

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